

	KPC Western Desert - EGYPT QASR COMPRESSION PROJECT SIL ALLOCATION STUDY	
Project n° 3538-200	DOCUMENT TITLE: SIL VERIFICATION REPORT DOCUMENT NUMBER: 13182I-006	Rev. No.: 0 September 2013

KPC

QASR COMPRESSION STATION PROJECT

SIL ALLOCATION REPORT

0	06-09-2013	ISSUED FOR APPROVAL	GC	LA	MGR
REV	DATE	DESCRIPTION	BY	CH'D	APP'D

	KPC Western Desert - EGYPT QASR COMPRESSION PROJECT SIL ALLOCATION STUDY	
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1 INTRODUCTION AND SCOPE

1.1 GENERAL PROJECT DESCRIPTION

QASR is a large, normally pressured gas-condensate reservoir located in the Western Desert of Egypt approximately 525 km west of Cairo. The field is operated by Khalda Petroleum Company (KPC), a joint venture between Apache Corporation and Egyptian General Petroleum Company (EGPC).

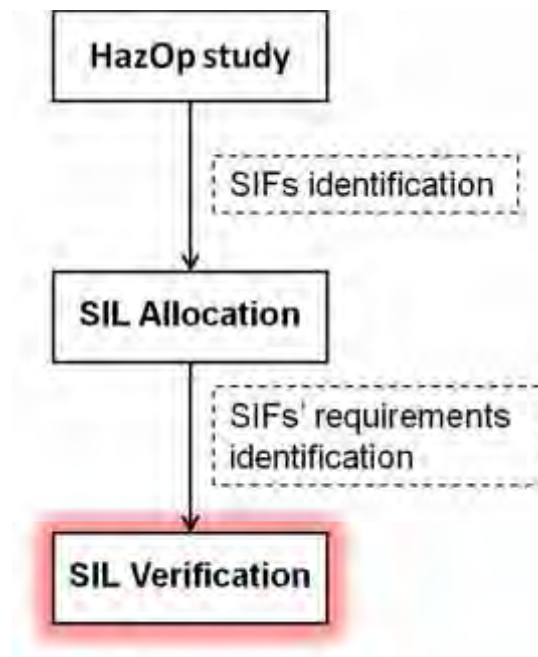
Field production is initially handled at the Start of Line (SOL) QASR Plant. After initial treatment (cooling and water removal) the gas/condensate is exported to a combination of the Salam, Tarek and Obaiyed gas plants for further treatment. The Qasr gas and condensate currently free flows from the wellheads through the QASR Phase I and Phase II facilities and export pipelines to the SHAMS manifold and Salam gas plant under reservoir pressure. As the reservoir pressure declines the peak gas rate of 800 mmscfd will no longer be achievable. The QASR Compression Project is designed to improve recovery as the reservoir production rate and pressure decline. The QASR Compression Project scope comprises:

- Gas turbine driven single stage compressor sets
- Condensate export pumps
- Utility systems

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SIL VERIFICATION OBJECTIVE

The objective of present document is to provide numerical verification that the required PFDs as stated in the SIL Allocation report, document n. 13182I-04 are actually fulfilled.



Verification has been carried out according to the indications and formulas provided by the IEC 61508 and IEC 61511 (reference document n. 04 and n. 05).

The detailed procedure adopted for the project is included in **Attachment A**.

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2 EXECUTIVE SUMMARY

2.1 PFD requirements verification

The verification has been performed according to reliability data gathered mainly from databank (Exida) since no specific information from vendors were available at this stage of the project.

Starting from such data, approximately 72% of the total SIFs is verified in terms of PFD requirements. Most of not-verified SIFs are those for which during the allocation PHASE a SIL2 requirement was deemed as necessary.

For what it concerns the SIFs that are not verified, the “mean discrepancy” between required PFD and calculated PFD is about 390% (the actual PFD is almost four times higher than the required value).

Evaluating in detail the components whose contribution is more significant in exceeding the limit of the required PFD the following considerations apply:

- the contribution of the **logic solver** is never governing (very low PFD)
- the contribution of the **sensors** is never governing when redundancy is provided (e.g. 2oo3) while is sometimes important for single instrument arrangement;
- the contribution of the **final element** is almost always governing in case of valves, unless redundancy is provided while is usually not crucial for other final elements (relays to de-energize compressors etc.).

According to such results and before planning significant changes in the design to solve the not verified contingencies (e.g. redundancy of the sensors / final elements) it is strongly suggested to search for more specific data on:

1. Sensors (level transmitter, pressure transmitter etc.)
2. Final elements (in particular valves)

The specific data might provide failure rates that can be of one order of magnitude lower than the generic values. Hence, the existing architecture could already guarantee a significantly lower PFD and fulfil the requirements.

In any case the present verification shall be updated when actual data from vendors are made available.

The table here below provides the detailed results of verification, with indication of the obtained results for each SIF.

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SIF #	INITIATOR	Std. Arch.	Selected SIL (all.)	Required PFD	Calculated PFD	PFD Verified
1	LIT011B HH	1	2	4,762E-03	4,791E-02	no
2	LIT002_032 HH	2	2	9,091E-03	4,455E-02	no
3	LIT037_344 HH	2	2	9,091E-03	4,455E-02	no
4	PIT079A/B/C LL	3	1	6,667E-02	4,461E-02	yes
5	PDIT906 HH	4	1	2,000E-02	1,548E-02	yes
6	PDIT907 HH	4	1	2,000E-02	1,548E-02	yes
7	LIT101 LL	5	1	1,000E-01	1,827E-02	yes
8	LIT107 HH	6	2	5,000E-03	3,082E-02	no
9	PIT110 LL	7	1	5,000E-02	2,806E-02	yes
10	PIT111 HH	7	1	1,538E-02	2,806E-02	no
11	TIT102 HH	8	1	2,000E-02	2,679E-02	no
12	VSHH101 HH	9	1	6,667E-02	2,619E-02	yes
13	LIT109 LL	5	1	1,000E-01	1,827E-02	yes
14	LIT110 HH	6	1	9,524E-02	3,082E-02	yes
15	TIT111 HH	8	1	1,000E-01	2,679E-02	yes
16	TIT110 HH	8	1	1,000E-01	2,679E-02	yes
17	TIT113 LL	10	2	3,960E-03	1,549E-02	no
18	TIT108A_B_C HH	11	2	9,091E-03	2,417E-02	no
19	VSHH102A/B/C/D HH	12	1	1,000E-01	1,488E-02	yes
20	LIT104A LL	-	NC	1,000E+00	1,159E-02	-
21	LIT104B HH	6	2	3,333E-03	3,082E-02	no
22	PDIT908 HH	4	1	2,000E-02	1,548E-02	yes
23	PDIT909 HH	4	1	2,000E-02	1,548E-02	yes
24	LIT011A LL	13	1	1,000E-01	9,821E-03	yes
25	PIT066A/B LL	-	NC	9,091E-01	7,002E-03	-
26	PIT929A/B HH	-	NC	1,667E-01	7,002E-03	-
27	LIT 001 LL	14	1	2,000E-02	6,852E-03	yes
28	LIT 004 LL	14	1	2,000E-02	7,002E-03	yes
29	PDIT910_911 HH	4	1	2,000E-02	1,548E-02	yes
30	PDIT912_913 HH	4	1	2,000E-02	1,548E-02	yes
31	PIT924 HH	15	1	1,000E-01	2,660E-02	yes
32	PIT076A_B_C HH	16	2	1,000E-02	2,280E-02	no
33	LIT002A/3A LL	17	1	1,000E-01	2,530E-02	yes
34	LIT002B/3B HH	5	2	4,545E-03	1,827E-02	no
35	PIT002A/B HH	18	2	1,916E-03	1,548E-02	no
36	LIT021A/B LL	5	1	1,000E-01	1,827E-02	yes
37	VSHH002A/B/C HH	19	1	1,000E-01	5,958E-03	yes
38	PIT918A/B/C HH	-	NC	1,000E+00	7,002E-03	-

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SIF #	INITIATOR	Std. Arch.	Selected SIL (all.)	Required PFD	Calculated PFD	PFD Verified
39	FIT019A/B/C HH	-	NC	2,500E-01	2,078E-02	-
40	PIT062 HH	-	NC	1,000E+00	4,505E-03	-
41	PIT071A/B LL	-	NC	1,000E+00	1,826E-02	-
42	PIT021A/B HH	20	1	1,000E-01	1,826E-02	yes
43	TIT004A/B HH	21	1	1,000E-01	1,697E-02	yes
44	TIT002A/B HH	-	not assessed	not assessed	1,697E-02	-
45	ST001A/B HH	-	not assessed	not assessed	1,826E-02	-
46	PDIT028 HH	4	1	2,000E-02	1,548E-02	yes
47	PDIT035 HH	22	1	2,000E-02	1,203E-02	yes
48	PDIT099 HH	4	1	2,000E-02	1,548E-02	yes
49	PDIT925 HH	4	1	2,000E-02	1,548E-02	yes
50	TIT007 HH	23	1	9,950E-02	5,610E-03	yes
51	TIT005 HH	23	1	1,000E-01	5,610E-03	yes
52	FIT026 B LL	24	1	1,000E-01	1,984E-02	yes
53	TIT011A/B HH	23	1	9,950E-02	5,610E-03	yes
54	TIT009A/B HH	23	2	9,950E-03	5,610E-03	yes
55	FIT027 LL	24	1	1,000E-01	1,984E-02	yes
56	LIT005 B LL	5	1	1,000E-01	1,827E-02	yes
57	LIT005 A HH	25	2	5,000E-03	2,255E-02	no
58	FIT004 LL	26	1	9,091E-02	2,241E-02	yes
59	PIT044A HH	27	2	5,000E-03	1,976E-02	no
60	PIT044B LL	27	2	5,000E-03	1,976E-02	no
61	PITXX1 HH [1]	18	2	1,000E-02	1,548E-02	no
62	TIT022A/B HH	23	1	9,950E-02	5,610E-03	yes
63	TIT019A/B HH	23	2	9,950E-03	5,610E-03	yes
64	TDIT034 LL	28	2	1,000E-02	9,717E-02	no
65	LIT008A LL	5	1	1,000E-01	1,827E-02	yes
66	PIT053B LL	29	3	1,000E-03	1,805E-02	no
67	PIT053B HH	30	2	5,000E-03	3,415E-02	no
68	TIT036 HH	23	1	9,950E-02	5,610E-03	yes
69	TIT037 HH	23	2	9,950E-03	5,610E-03	yes
70	FIT028 B LL	24	1	1,000E-01	1,984E-02	yes
71	PIT075A LL	18	1	5,000E-02	1,548E-02	yes
72	PIT075B LL	27	1	5,000E-02	1,976E-02	yes
73	PIT075C LL	27	1	5,000E-02	1,976E-02	yes
74	PIT085A/B/C LL	31	1	9,091E-02	8,166E-03	yes
75	TIT014 HH	23	1	9,950E-02	5,610E-03	yes

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SIF #	INITIATOR	Std. Arch.	Selected SIL (all.)	Required PFD	Calculated PFD	PFD Verified
76	TIT006 HH	23	2	9,901E-03	5,610E-03	yes
77	PITXX2 HH [2]	18	1	1,000E-01	1,548E-02	yes

Notes:

[1]: Additional Safety Instrumented Function as per HAZOP recommendation n. #52

[2]: Additional Safety Instrumented Function as per HAZOP recommendation n. #40

Detailed PFD Calculation by FTA are provided on **Attachment D**.

2.2 Architectural requirements verification

The following table provides details relevant to the verification of the architectural constraints, according to indication reported in IEC 61511-1.

SIF #	INITIATOR	Std. Arch.	Selected SIL (all.)	PFD Verified	SFF Verified
1	LIT011B HH	1	2	no	no (valves body #12)
2	LIT002_032 HH	2	2	no	no (valves body #12)
3	LIT037_344 HH	2	2	no	no (valves body #12)
4	PIT079A/B/C LL	3	1	yes	yes
5	PDIT906 HH	4	1	yes	yes
6	PDIT907 HH	4	1	yes	yes
7	LIT101 LL	5	1	yes	yes
8	LIT107 HH	6	2	no	no (LT #2, valves body #12)
9	PIT110 LL	7	1	yes	yes
10	PIT111 HH	7	1	no	yes
11	TIT102 HH	8	1	no	yes
12	VSHH101 HH	9	1	yes	yes
13	LIT109 LL	5	1	yes	yes
14	LIT110 HH	6	1	yes	yes
15	TIT111 HH	8	1	yes	yes
16	TIT110 HH	8	1	yes	yes
17	TIT113 LL	10	2	no	yes
18	TIT108A_B_C HH	11	2	no	no (valves body #12)
19	VSHH102A/B/C/D HH	12	1	yes	yes
20	LIT104A LL	-	NC	-	-
21	LIT104B HH	6	2	no	no (valves body #12)
22	PDIT908 HH	4	1	yes	yes
23	PDIT909 HH	4	1	yes	yes
24	LIT011A LL	13	1	yes	yes

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SIF #	INITIATOR	Std. Arch.	Selected SIL (all.)	PFD Verified	SFF Verified
25	PIT066A/B LL	-	NC	-	-
26	PIT929A/B HH	-	NC	-	-
27	LIT 001 LL	14	1	yes	yes
28	LIT 004 LL	14	1	yes	yes
29	PDIT910_911 HH	4	1	yes	yes
30	PDIT912_913 HH	4	1	yes	yes
31	PIT924 HH	15	1	yes	yes
32	PIT076A_B_C HH	16	2	no	yes
33	LIT002A/3A LL	17	1	yes	yes
34	LIT002B/3B HH	5	2	no	no (LT #2, valves body #12)
35	PIT002A/B HH	18	2	no	no (valves body #12)
36	LIT021A/B LL	5	1	yes	yes
37	VSHH002A/B/C HH	19	1	yes	yes
38	PIT918A/B/C HH	-	NC	-	-
39	FIT019A/B/C HH	-	NC	-	-
40	PIT062 HH	-	NC	-	-
41	PIT071A/B LL	-	NC	-	-
42	PIT021A/B HH	20	1	yes	yes
43	TIT004A/B HH	21	1	yes	yes
44	TIT002A/B HH	-	not assessed	-	-
45	ST001A/B HH	-	not assessed	-	-
46	PDIT028 HH	4	1	yes	yes
47	PDIT035 HH	22	1	yes	yes
48	PDIT099 HH	4	1	yes	yes
49	PDIT925 HH	4	1	yes	yes
50	TIT007 HH	23	1	yes	yes
51	TIT005 HH	23	1	yes	yes
52	FIT026 B LL	24	1	yes	yes
53	TIT011A/B HH	23	1	yes	yes
54	TIT009A/B HH	23	2	yes	yes
55	FIT027 LL	24	1	yes	yes
56	LIT005 B LL	5	1	yes	yes
57	LIT005 A HH	25	2	no	no (LT #2, valves body #13)
58	FIT004 LL	26	1	yes	yes
59	PIT044A HH	27	2	no	no (valves body #13)
60	PIT044B LL	27	2	no	no (valves body #13)
61	PITXX1 HH [1]	18	2	no	yes

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SIF #	INITIATOR	Std. Arch.	Selected SIL (all.)	PFD Verified	SFF Verified
62	TIT022A/B HH	23	1	yes	yes
63	TIT019A/B HH	23	2	yes	yes
64	TDIT034 LL	28	2	no	yes
65	LIT008A LL	5	1	yes	yes
66	PIT053B LL	29	3	no	yes
67	PIT053B HH	30	2	no	no (valves body #13)
68	TIT036 HH	23	1	yes	yes
69	TIT037 HH	23	2	yes	yes
70	FIT028 B LL	24	1	yes	yes
71	PIT075A LL	18	1	yes	yes
72	PIT075B LL	27	1	yes	yes
73	PIT075C LL	27	1	yes	yes
74	PIT085A/B/C LL	31	1	yes	yes
75	TIT014 HH	23	1	yes	yes
76	TIT006 HH	23	2	yes	yes
77	PITXX2 HH [2]	18	1	yes	yes

Notes:

- [1]: Additional Safety Instrumented Function as per HAZOP recommendation n. #52
- [2]: Additional Safety Instrumented Function as per HAZOP recommendation n. #40

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3 METHODOLOGY

3.1 DEFINITIONS

COMPANY	KPC
PROJECT	QASR Compression
CONTRACTOR	ENPPI
CONSULTANT	The party which will perform the study (ICARO)

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3.2 ACRONYMS

BDV	Blow-Down Valve
BPCS	Basic Process Control System
C&ED	Cause and Effects Diagram
DCS	Distributed Control System
ESD	Emergency Shut Down
ESDV	Emergency Shut Down Valve
FEED	Front End Engineering Design
F&G	Fire and Gas
HAZOP	Hazard and operability study
HFT	Hardware Fault Tolerance
HSE	Health, Safety & Environment
IE	Initiating Event
IEC	International Electro technical Commission
IEL	Intermediate Event Likelihood
IPL	Independent Protection Layer
LOPA	Level Of Protection Analysis
MTTR	Mean Time To Restoration
P&ID	Piping and Instrumentation Diagram
PES	Programmable Electronic System
PLC	Programmable Logic Controller
PFD	Probability of Failure on Demand
PSV	Pressure Safety Valve
PVST	Partial Valve Stroke Test
SFF	Safe Failure Fraction
SIF	Safety Instrumented Function
SIL	Safety integrity Level
TI	Inspection Time

3.3 MAIN ASSUMPTIONS

- Selected PLC for ESD is FANUC GMR series 90-70 PLC with Genius Block I/O's. PFD is assumed to be the sum of PFDs calculated by vendor for a unit composed by genius simplex input, duplex 1002 90-70 logic unit, simplex output;
- According to vendor's reference information, for PLC a test interval of 6 months and a MTTR of 8 hours have been assumed;

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- For all others components a test interval of 12 months and a MTTR of 8 hours have been assumed.
- PLC is assumed to fulfill the architectural requirements (HFT/ SFF) due to unavailability of detailed failure rates (safe/ dangerous; detected/ undetected) in vendor's documents;
- All other reliability data are taken from EXIDA (see ref. [6]);
- Vibration switch assumed to be magnetic (if EXIDS's data for piezoelectric, it would be not suitable for SIL1);
- The main compressor trip (actuated through vendor's UPC) is assumed to provide the 30% of the SIL budget required by the most stringent PFD for a SIF which activates the trip the compressor itself. Therefore the PFD requirement for the activation of main compressor trip has been assumed equal to 1.5E-03 (30% of 5E-03, which is PFD requirement for SIF #8);
- PVST test interval is assumed to be 1440 hours and effective for valves actuator and body
- Common Cause failure factor for redundant elements is assumed as 5% of dangerous undetected failure rate

3.4 VERIFICATION MAIN STEPS

SIL Verification of each Safety Instrumented Function (SIF) was performed through the following steps:

- SIF architectures definition and sketching up.
- Gathering of the reliability data of each SIF component.
- Calculation of total PFD of SIF and verification that calculated PFD and relevant calculated SIL level are consistent with the requirement arisen in SIL Allocation phase
- Verification of the architectural requirements (HFT/ SFF for each SIF components)

The detailed procedure adopted for the project is included in **Attachment A**.

The following table provides the correspondence between the analyzed SIFs and the relevant standard logic architectures that have been sketched up in **Attachment B**.

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SIF #	INITIATOR	PID	FINAL ELEMENT	PID	Std. Arch.
1	LIT011B HH	12311-2	C: ESDV-030A AND ESDV-031A AND ESDV032A AND ESDV033A	12210 /12353	1
2	LIT002_032 HH	12369	C: ESDV-030A AND ESDV-031A AND ESDV032A AND ESDV033A	12210	2
3	LIT037_344 HH	12356	C: ESDV-030A AND ESDV-031A AND ESDV032A AND ESDV033A	12210	2
4	PIT079A/B/C LL	12300-2	C: ESDV-030A AND ESDV-031A AND ESDV032A AND ESDV033A	12210	3
5	PDIT906 HH	12210	I: ESDV-030A	12210	4
6	PDIT907 HH	12210	I: ESDV-031A	12210	4
7	LIT101 LL	12211	C: ESDV103	12211	5
8	LIT107 HH	12211	T: QA-K-8001A AND ESDV101A AND ESDV102A	12212	6
9	PIT110 LL	12212	T: QA-K-8001A AND ESDV101A AND ESDV102A	12212	7
10	PIT111 HH	12212	T: QA-K-8001A AND ESDV101A AND ESDV102A	12212	7
11	TIT102 HH	12212	T: QA-K-8001A AND ESDV101A AND ESDV102A	12212	8
12	VSHH101 HH	12212	T: QA-K-8001A AND ESDV101A AND ESDV102A	12212	9
13	LIT109 LL	12212	C: ESDV109	12212	5
14	LIT110 HH	12212	T: QA-K-8001A AND ESDV101A AND ESDV102A	12212	6
15	TIT111 HH	12212	T: QA-K-8001A AND ESDV101A AND ESDV102A	12212	8
16	TIT110 HH	12212	T: QA-K-8001A AND ESDV101A AND ESDV102A	12212	8
17	TIT113 LL	12213	T: ESD110A (QA-E-8001A cooler motor)	12213	10
18	TIT108A_B_C HH	12213	T: QA-K-8001A AND ESDV101A AND ESDV102A	12212	11
19	VSHH102A/B/C/D HH	12213	T: QA-E-8001A/B/C/D	12212	12
20	LIT104A LL	12214	C: ESDV101 A	12211	-
21	LIT104B HH	12214	T: QA-K-8001A AND ESDV101A AND ESDV102A	12212	6
22	PDIT908 HH	12353	I: ESDV032A	12353	4
23	PDIT909 HH	12353	I: ESDV033A	12353	4
24	LIT011A LL	12311-2	T: P-8006A/B	12311-2	13
25	PIT066A/B LL	12312	T: P-8007A/B	12312	-
26	PIT929A/B HH	12312	T: P-8007A/B	12312	-

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SIF #	INITIATOR	PID	FINAL ELEMENT	PID	Std. Arch.
27	LIT 001 LL	12372	T: P-3016	12372	14
28	LIT 004 LL	12373	T: P-4016	12373	14
29	PDIT910_911 HH	12353	I: ESDV034A/35A	12353	4
30	PDIT912_913 HH	12353	I: ESDV036A/37A	12353	4
31	PIT924 HH	12353	C: ESDV-034A AND ESDV 035A	12353	15
32	PIT076A_B_C HH	12366	C: ESDV-026A AND B	12250/54	16
33	LIT002A/3A LL	12250-54	C: ESDV001A/B AND T: QA-P-8003A/B/C	12250/54	17
34	LIT002B/3B HH	12250-54	C: ESDV011A/B	12250/54	5
35	PIT002A/B HH	12250-54	C: ESDV011A/B	12250/54	18
36	LIT021A/B LL	12250	C: ESDV026A/B	12250/54	5
37	VSHH002A/B/C HH	12251	T: QA-P-8003A/B/C	12251	19
38	PIT918A/B/C HH	12251	T: QA-P-8003A/B/C	12251	-
39	FIT019A/B/C HH	12251	T: QA-P-8003A/B/C	12251	-
40	PIT062 HH	12262	C: ESDV-013A OR B	12262	-
41	PIT071A/B LL	12261 / 62	T: QA-K-8003A/B AND C: ESDV043 AND ESDV013A OR ESDV013B	12250/61/62	-
42	PIT021A/B HH	12261 / 62	T: QA-K-8003A/B AND C: ESDV043 AND ESDV013A OR ESDV013B	12250/61/62	20
43	TIT004A/B HH	12261 / 62	T: QA-K-8003A/B AND C: ESDV043 AND ESDV013A OR ESDV013B	12250/61/62	21
44	TIT002A/B HH	12261 / 62	T: QA-K-8003A/B AND C: ESDV043 AND ESDV013A OR ESDV013B	12250/61/62	-
45	ST001A/B HH	12261 / 62	T: QA-K-8003A/B AND C: ESDV043 AND ESDV013A OR ESDV013B	12250/61/62	-
46	PDIT028 HH	12302	I: ESDV002A	12302	4
47	PDIT035 HH	12303-1	I: ESDV004A	12303-1	22
48	PDIT099 HH	12354	I: ESDV010A	12354	4
49	PDIT925 HH	12368	I: ESDV028A	12368	4
50	TIT007 HH	12302	T: QA-E-8002	12302	23
51	TIT005 HH	12302	T: QA-E-8002	12302	23
52	FIT026 B LL	12302	T: QA-E-8002	12302	24
53	TIT011A/B HH	12303-01/02	T: QA-E-8003A/B	12303-01/02	23
54	TIT009A/B HH	12303-01/02	T: QA-E-8003A/B	12303-01/02	23
55	FIT027 LL	12303-01/02	T: QA-E-8003A/B	12303-01/02	24
56	LIT005 B LL	12305	C: ESDV 005	12305	5
57	LIT005 A HH	12305	C: ESDV003 AND ESDV004		25
58	FIT004 LL	12305	T: QA-E-8005A AND B	12307-1	26

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SIF #	INITIATOR	PID	FINAL ELEMENT	PID	Std. Arch.
59	PIT044A HH	12305	ESDV003 AND 004A/B	12302/ 120303-1	27
60	PIT044B LL	12305	ESDV003 AND 004A/B	12302/ 120303-1	27
61	PITXX1 HH [1]	12307	ESDVXX1	-	18
62	TIT022A/B HH	12307-1	T: QA-E-8005A/B	12307-1	23
63	TIT019A/B HH	12307-1	T: QA-E-8005A/B	12307-1	23
64	TDIT034 LL	12307-1	T: QA-K-8001A AND ESDV101A AND ESDV102A AND T: QA-K-8001B AND ESDV201A AND ESDV202A AND T: QA-K-8001C AND ESDV301A AND ESDV302A AND T: QA-K-8001D AND ESDV401A AND ESDV402A	12213,122 23, 12233, 12243	28
65	LIT008A LL	12308-2	C: ESDV 008	12308-2	5
66	PIT053B LL	12308-2	O: ESDV025 AND ESDV048	12354/ 12368	29
67	PIT053B HH	12308-2	C: ESDV025 AND ESDV048 AND ESDV007	12308-1/ 12354/ 12368	30
68	TIT036 HH	12308-1	T: QA-E-8006	12308-1	23
69	TIT037 HH	12308-1	T: QA-E-8006	12308-1	23
70	FIT028 B LL	12308-1	T: QA-E-8006	12308-1	24
71	PIT075A LL	12300-1	C: ESDV038	12300-1	18
72	PIT075B LL	12300-1	C: ESDV015	12300-1	27
73	PIT075C LL	12300-1	C: ESDV016	12300-1	27
74	PIT085A/B/C LL	12301-2	C: ESDV024	12301-2	31
75	TIT014 HH	12301-2	T: QA-E-8007	12301-2	23
76	TIT006 HH	12301-2	T: QA-E-8007	12301-2	23
77	PITXX2 HH [2]	12301-2	ESDVXX2	-	18

Every architecture analyzed includes the reference to the data included in reference data base for the present SIL Verification study.

Selected reliability data are summarized in **Attachment C**

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4 WORKING AND REFERENCE DOCUMENTATION

Reference documentation is listed here below.

- [1] HAZOP report – refer to document n. 13182I-003
- [2] SIL Allocation report – refer to document n. 13182I-004
- [3] C&E diagram (document n. 3538-200-KCB-001)
- [4] IEC 61508, Functional Safety of Electrical/ Electronic/ Programmable Electronic Safety Related Systems.
- [5] IEC 61511, Functional Safety: safety instrumented systems for the process industry sector.
- [6] Exida 2007, Safety Equipment Reliability Handbook, Exida – 3rd Edition, 2007.
- [7] GE Fanuc Manuals, Genius, GFK-1649

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ATTACHMENT A - PROCEDURE FOR SIL VERIFICATION STUDY



Project n° 3538-200

PO N.° 3538-200-10-RT-041-4

Doc. N° 13182I-002

KPC

QASR COMPRESSION STATION PROJECT

**PROCEDURE FOR SIL VERIFICATION
STUDY**

0	26-08-2013	ISSUED FOR APPROVAL	GC	LA	MGR
REV	DATE	DESCRIPTION	BY	CH'D	APP'D



Project n° 3538-200

PO N.° 3538-200-10-RT-041-4

Doc. N° 13182I-002

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1 INTRODUCTION

1.1 General project description

QASR is a large, normally pressured gas-condensate reservoir located in the Western Desert of Egypt approximately 525 km west of Cairo. The field is operated by Khalda Petroleum Company (KPC), a joint venture between Apache Corporation and Egyptian General Petroleum Company (EGPC).

Field production is initially handled at the Start of Line (SOL) Qasr Plant. After initial treatment (cooling and water removal) the gas/condensate is exported to a combination of the Salam, Tarek and Obaiyed gas plants for further treatment. The Qasr gas and condensate currently free flows from the wellheads through the Qasr Phase I and Phase II facilities and export pipelines to the SHAMS manifold and Salam gas plant under reservoir pressure. As the reservoir pressure declines the peak gas rate of 800 mmscfd will no longer be achievable. The QASR Compression Project is designed to improve recovery as the reservoir production rate and pressure decline. The Qasr Compression Project scope comprises:

- Gas turbine driven single stage compressor sets
- Condensate export pumps
- Utility systems

1.2 Scope

This procedure defines modalities and methodologies to be followed in developing the SIL Verification Study for the QASR Compression Project.

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1.3 List of definitions and abbreviations

1.3.1 Definitions

Company	KPC
Project	QASR Compression
Contractor	ENPPI
Consultant	The party which will perform the study (ICARO)
Basic Process Control System	The system that responds to input signals from the process and generates output signals to maintain operation of the process in a desired state. The system does not perform functions assessed as SIL 1 or higher.
Beta Factor	The number of Common Mode Failures (of robust Initiators or Final Elements), expressed as a fraction of all possible Failures.
Common Mode Failure	A Failure having the potential to affect all duplicated components in a robust configuration by virtue of common or shared characteristics.
Dangerous Failure	A Failure that has the potential to place the SIF in a state in which it will fail to perform its function. Dangerous Failures are usually only safe when the system has to perform a certain action or through testing. Also known as unrevealed failure.
Dangerous Failure Rate	The number of Dangerous Failures per unit time.
Demand Rate	The frequency at which a Demand occurs, i.e., the number of Demands per unit time.
Detected Failure	A failure that is detected by internal diagnostics
Diagnostic Coverage Factor	The number of Dangerous Failures that diagnostic features are capable of detecting, expressed as a fraction of all possible dangerous failures. (NOTE: Diagnostic features may only be recognised as such if they can trip the process to a safe state or maintain safety by different means.)
Design Intent	Protective action of the Safety Instrumented Function
Failure	An abnormal condition that may cause a reduction or loss of capability of the SIF to perform its intended function.
Failure Rate	The Failure rate indicates the number of failures per unit operating hours.

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Final Element	A device, or combination of devices, that manipulate a process variable or attract the attention of the operator to achieve risk reduction. The Final Element includes output cards or output relays, solenoid valves and cabling. Examples are valves, switchgear (rotating equipment stop circuits) and alarms.
Hardware Fault Tolerance	Capacity of the system or component to continue to guarantee the correct functionality even in case of one or more failure of its hardware.
Hazard or Hazardous Situation	A situation with the potential to cause harm, including ill health and injury, damage to property, products or the environment, production losses or increased liabilities.
Initiator	A device, or combination of devices, that indicates whether a process or equipment item is operating outside the operating envelope. In IEC 61508/61511 an Initiator is referred to as a Sensor.
Independent Protection Layer	Device, system, or action that is capable of preventing a postulated accident sequence from proceeding to a defined, undesirable endpoint. An IPL is (1) independent of the event that initiated the accident sequence and (2) independent of any other IPLs. IPLs are normally identified during layer of protection analyses.
Inspection Time	Time interval between proof tests
Intermediate Event Likelihood	Frequency of the undesired event before the mitigating factor provided the the SIF
Logic Solver	The portion of a SIF that performs the application logic function. The Logic Solver excludes trip amplifiers, input cards and output cards. Examples are electromechanical relays, solid-state/magnetic-core logic and the CPU section of programmable electronic systems.
Mean Time To Restoration	Time interval to repair the failing component. Includes repair time, shipping and managing time
Mitigation	The action of making a consequence less severe or relieving consequences.
Partial Valve Stroke Test	Technique to test a percentage of the possible failure modes of a valve without the need to physically fully close the valve itself.
Probability of Failure on Demand	The probability (dimensionless) of the SIF failing to respond to a Demand.

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Programmable electronics	Electronic component or device forming part of a PES and based on computer technology. The term encompasses both hardware and software and input and output units. (Examples of process sector programmable electronics include: smart sensors; final elements; and programmable electronic logic solvers, such as, programmable controllers, PLCs, DCS, loop controllers.)
Proof Test	A test carried out on SIF components against an approved procedure to confirm that all requirements of the SIF are met.
Risk	The frequency at which a Hazardous Situation occurs multiplied by the consequence of the Hazardous Situation.
Safe Failure	A Failure whose occurrence does not have the potential to place a SIF in a dangerous state. Also known as revealed failure.
Safe Failure Rate	The number of Safe Failures per unit time.
Safe Failure Fraction	The safe failure fraction (SFF) is the fraction of the overall failure rate of a device that results in either a safe fault or a diagnosed unsafe fault.
Safety Instrumented Function	A function comprising one or more Initiators, a Logic Solver and one or more Final Elements whose purpose is to prevent or mitigate hazardous situations. A SIF is intended to achieve or maintain a safe state for the process, in respect of a specific hazardous event.
Safety Integrity Level	Dangerous failure class 1, 2, 3 or 4 derived from the consequences of failure on demand and the frequency of demand. The definition in IEC 61511: discrete level (one out of four) for specifying the safety integrity requirements of the SIF to be allocated to the SIS (trip systems). Safety integrity level 4 has the highest level of safety integrity; safety integrity level 1 has the lowest.
Target Mitigated Event Likelihood	Maximum acceptable frequency for specified severity of consequence of the undesired event
Time Risk	The fraction of overall year time during which the SIF is asked to be active. Normally for continuous operating unit, Time risk is set to 1; for intermittent process, Time risk is set to a fraction value.
Trip	An SIF action to bring the Final Element to a safe state.
Unetected Failure	A failure that is not detected by internal diagnostics

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Validation

Confirmation that the system under consideration fully meets the integrity requirements set forth in the associated SIF Requirements Specification.

Verification

Demonstration for a particular life-cycle phase that all deliverables (documents, software, hardware) meet the objectives set for that phase.

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1.3.2 Abbreviations

AIL	Assets Integrity Level
BDV	Blow-Down Valve
BPCS	Basic Process Control System
C&ED	Cause and Effects Diagram
DCS	Distributed Control System
ESD	Emergency Shut Down
ESDV	Emergency Shut Down Valve
F&G	Fire and Gas
HAZOP	Hazard and operability study
HFT	Hardware Fault Tolerance
IE	Initiating Event
IEC	International Electro technical Commission
IEL	Intermediate Event Likelihood
IPL	Independent Protection Layer
LOPA	Level Of Protection Analysis
MTTR	Mean Time To Restoration
P&ID	Piping and Instrumentation Diagram
PES	Programmable Electronic System
PLC	Programmable Logic Controller
PFD	Probability of Failure on Demand
PSV	Pressure Safety Valve
PVST	Partial Valve Stroke Test
SFF	Safe Failure Fraction
SIF	Safety Instrumented Function
SIL	Safety integrity Level
TI	Inspection Time

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1.4 References

- o IEC 61508-2008 “ Functional safety of electrical/electronic/programmable electronic safety-related systems”.
- o IEC 61511-2003 “ Functional safety – Safety instrumented systems for the process industry sector.

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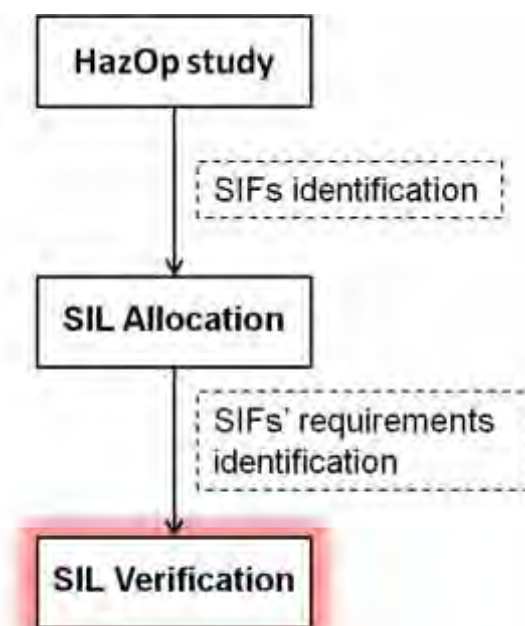
2 SIL VERIFICATION PURPOSE AND GENERAL DESCRIPTION

2.1 SIL Verification purpose and main topics

A Safety System Design Process typically comprehends three main steps, as sketched up in figure 1. HAZOP study is normally the first step, followed by Safety Integrity Level (SIL) analysis. SIL analysis foresees the Allocation phase and Verification phase.

While the HAZOP process normally discovers potential hazards and provides general recommendations, the SIL is a specific analysis which defines the Safety Criteria and Mitigation of hazards which can lead to a significant safety, environmental and economic consequences.

SIL analysis is performed according to the IEC 61508 ¹ extensive standard, which is essentially a framework for implementing instrumented safety systems using the principle of Safety Life Cycle, and the IEC 61511 ², developed as a Process Sector implementation of IEC 61508.



To perform SIL analysis, Safety Instrumented Functions (SIFs) have to be identified, which is one of the goals of HAZOP study.

A Safety Instrumented Function (SIF) is a function to be implemented by a Safety Instrumented System (SIS), composed mainly by sensors (e.g. transmitters), logic

¹ Functional safety of electrical/electronic/programmable electronic safety-related systems

² Functional safety – Safety instrumented systems for the process industry sector

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solvers and final elements (e.g. solenoids), which is intended to achieve or maintain a safe state for the process, with respect to a specific hazardous event.

Each key SIF must be evaluated for the severity of the protected risk, either in terms of safety issues, asset losses or environmental concerns, and therefore the performances of the SIF must be commensurate with the risk. The performance level for each SIF must address both the reliability and availability requirements of the SIF. Both of these factors are combined into a single index termed SIL. SIL is defined as the likelihood of the system satisfactorily performing the required safety function under all the stated conditions within a stated period of time.

Defining the reliability and availability requirements of SIFs, and therefore the SIL index ratings, is the main aim of SIL Allocation phase.

To determine SIL rating required for each SIF, during SIL Allocation phase the Probability to Fail on Demand (PFD) is identified.

The SIL ratings can then be related to the PFD of the relevant SIF. Relationship between SIL and Probability of Failure on Demand is indicated in Table 1 in case of Shut Down Systems (not continuously operating systems ³).

Safety Integrity Level (SIL)	Probability of failure on demand (PFD)
4	$10^{-4} > \text{PFD} \geq 10^{-5}$
3	$10^{-3} > \text{PFD} \geq 10^{-4}$
2	$10^{-2} > \text{PFD} \geq 10^{-3}$
1	$10^{-1} > \text{PFD} \geq 10^{-2}$

ØŞÜİİ H ÖTİWÜÜÜİŞTWTTÜÖÜŞWİF ŞÜT ÖNÖŞŞŞÜMİŞTİŞÜİÜİÜİŞÜT

The objective of SIL Verification phase is to verify that each SIF fulfills the SIL rating identified in SIL Allocation phase. The verification is performed calculating the PFD of each SIF, basing on reliability data supplied by SIF's components vendor (if available) or selected from referenced data banks.

³ Low Demand Mode: where frequency of demands for operation made on a safety-related system is no greater than one per year and no greater than twice the proof-test frequency (IEC 61508-4)

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3 METHODOLOGY

SIL Verification of each Safety Instrumented Function (SIF) shall be performed through the following steps:

1. **Logical representation of the SIF architecture.**
2. **Gathering of the reliability data of each SIF component.**
3. **Calculation of total PFD of SIF and verification that calculated PFD and relevant calculated SIL level are consistent with the requirement arisen in SIL Allocation phase**
4. **Verification of the architectural requirements (Hardware fault tolerance / Safe Failure Fraction) for each component of the SIF, as per paragraph 7.4.3 of IEC 61508-2 and tables 2 and 3 (subsystem of type A or B)**

3.1 Definition of SIFs Architectures

In order to properly define the logical path that leads to a SIF unavailability (failure on demand), it is necessary to identify the architecture of each safety instrumented function.

In order to allow a correct and effective analysis, architectures of each SIF shall be sketched up showing:

- Sensors
- Logic Solver
- Final elements

An example of SIF architecture sketching is shown in present procedure's **Attachment 1**.

As far as final elements are concerned, it has to stressed that only the actions necessary to put in safe condition the system to be protected by the SIF have to be identified, neglecting all the complementary action which might be triggered by the same logic (shown in cause and effects matrixes).

As a matter of fact, due to minor / null criticality of possible failure on demand, the final elements related to these complementary actions might not have to strictly fulfill the same reliability and availability requirements of the final elements which are in charge to guarantee the actions genuinely defined as safety actions.

All the actions not necessary to reach the safe condition of the system to be protected will not be taken into account in SIL Verification step, and thus they will be neglected in SIF Architecture definition.

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3.1.1.1 Partial Valve Stroke Test

In case that, due to process constraints of the plant / system assessed, it is not acceptable to interrupt the operation to perform a SIF complete functionality test, it is possible to perform a Partial Stroke Test. The proof activates the SIF and can usually perform:

- Initiator: complete test
- Logic Solver: complete test
- Final elements: partial test

A partial valve stroke test might allow to verify the correct and complete performance of the solenoid, but only the partial displacement of the actuator and partial closing / opening of the valve. It therefore has an effectiveness which is lower than a complete proof test.

The necessary data to take into account that PVST is foreseen for some final elements of the SIF are:

- The subcomponents which are tested (e.g. only actuator/ actuator and body)
- Proof Test time interval (e.g. one month) for PVST

3.3 Reference for the selected reliability values

The reliability data shall be preferably taken from certificates / other technical documentation of the vendor.

The use of information from databank shall be limited as much as possible since it would lead to the following consequences:

- incertitude that the selected figures are effectively representative of the actual components;
- usually higher values of PFDavg leading to excessively conservative calculation.

In case that vendor's data are not available, the reliability data can be taken from the following source:

“Exida 2007: Safety Equipment Reliability Handbook, Exida – 3rd Edition, 2007”

Nevertheless if the information from Exide are selected, it shall be highlighted in the report that an additional and final verification of the figures hall be performed once the actual data from vendor are made available.

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3.4 Calculation of PFD

Average value of Probability of Failure on Demand (PFD) calculation of the whole safety function is performed in accordance with IEC 61508-6.

Probability of Failure on Demand (PFD) is given by the following equation:

$$PFD_{SIF} = PFD_S + PFD_{LS} + PFD_{FE}$$

where:

PFD_{SIF} Average Probability of Failure on Demand of Safety Function.

PFD_S Average Probability of Failure on Demand of Sensors.

PFD_{LS} Average Probability of Failure on Demand of Logic Solver.

PFD_{FE} Average Probability of Failure on Demand of Final Elements.

The average PFD calculation will be performed by means of software FTA-Pro by Dyadem, basing on Fault Tree Analysis (FTA) technique for quantitative calculation of systems unavailability.

Fault trees are built basing on the logic architecture of each Safety Instrumented Function analysed and using as input data the specific reliability figures collected for every component.

The Unavailability (Q) of the Safety Instrumented Function calculated at the medium point of mission time is assumed as average value of probability of failure on demand for the SIF under examination.

An example of FTA graphic outline and relevant calculation results is showed in **Attachment 3**.

3.5 Additional architectural requirements

With reference to IEC 61511-1, apart from verification of calculated average PFD/ calculated SIL level with the required PFD/ SIL level from SIL Allocation, there is a further requirement to be satisfied for every subcomponent of each safety instrumented function.

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4 WORKING DOCUMENTATION

4.1 Basic documents

Following is a list of documentation strictly necessary for the development of the SIL Verification study.

N	Document
1	HazOp report
2	SIL Allocation report
3	P&ID – Main plant
4	P&ID – Packages
5	Cause And Effect Diagram
6	Control, Shutdown And Process Safeguarding Philosophy (ESD Philosophy)
7	Vendor reliability data

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5 SIL VERIFICATION REPORT

5.1 Index

1. Scope of the study;
2. Executive summary
3. General plant description;
4. Methodology description;
5. Reference documentation;

Attachment 1 SIFs Architecture representation;

Attachment 2 Reliability data;

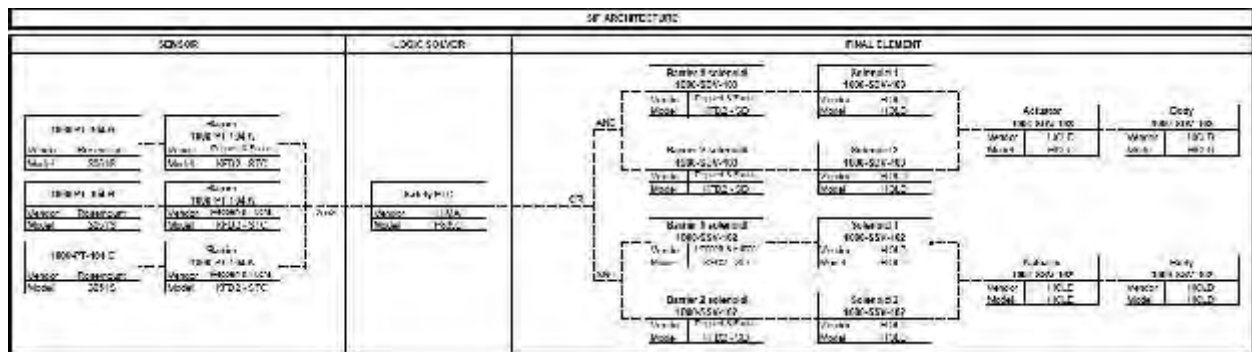
Attachment 3 PFD Calculation by FTA;

Attachment 4 Results summary (example shown in **Attachment 4** of this procedure).

Test interval and Mean Time to Restoration used shall be outlined in SIL Verification report and shall be fulfilled during plant operation, due to their sensitive influence on SIL verification results.

	KPC Western Desert - EGYPT QASR COMPRESSION STATION PROJECT SIL VERIFICATION STUDY	
Project n° 3538-200	DOCUMENT TITLE: PROCEDURE FOR SILVerification STUDY DOCUMENT NUMBER: 13182I-002	Rev. No.: 0 August 2013

ANNEX 1 – EXAMPLE OF SIF ARCHITECTURE



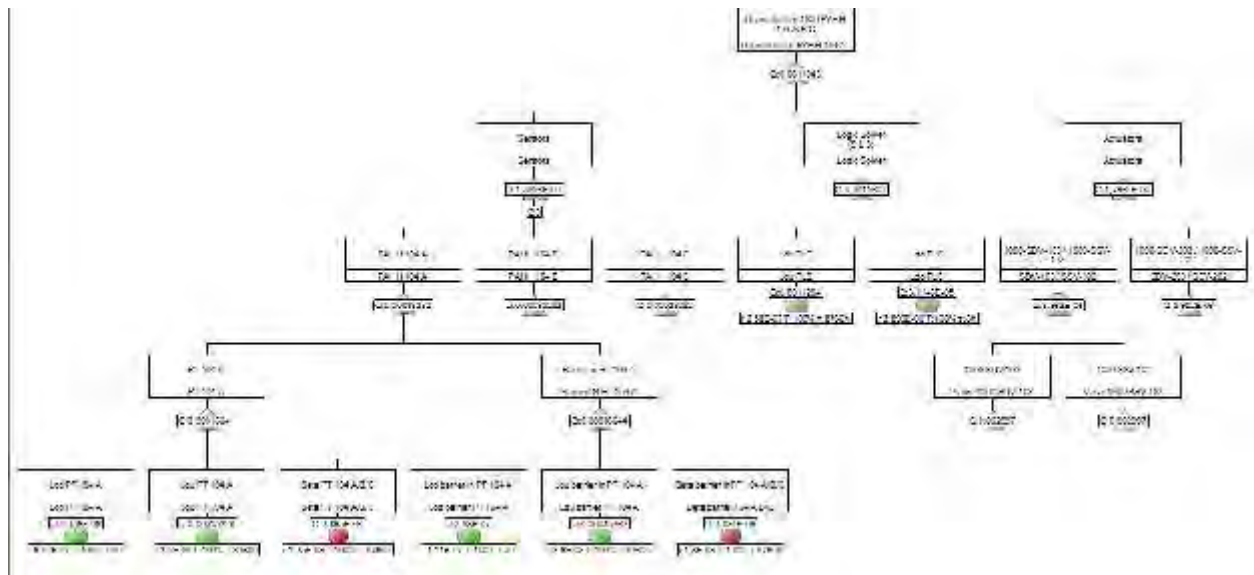
	KPC Western Desert - EGYPT QASR COMPRESSION STATION PROJECT SIL VERIFICATION STUDY	
Project n° 3538-200	DOCUMENT TITLE: PROCEDURE FOR SILVerification STUDY DOCUMENT NUMBER: 13182I-002	Rev. No.: 0 August 2013

ANNEX 2 – RELIABILITY DATA COLLECTION

Description	l_{DD}	l_{DU}	MTTR	SFF	TI	b	b_D	Source

	KPC Western Desert - EGYPT QASR COMPRESSION STATION PROJECT SIL VERIFICATION STUDY	
Project n° 3538-200	DOCUMENT TITLE: PROCEDURE FOR SILVerification STUDY DOCUMENT NUMBER: 131821-002	Rev. No.: 0 August 2013

ANNEX 3 – EXAMPLE OF PDF CALCULATION BY FTA



	KPC Western Desert - EGYPT QASR COMPRESSION STATION PROJECT SIL VERIFICATION STUDY	
Project n° 3538-200	DOCUMENT TITLE: PROCEDURE FOR SILVerification STUDY DOCUMENT NUMBER: 13182I-002	Rev. No.: 0 August 2013

ANNEX 4 – RESULTS SUMMARY

The following table illustrates the results of SIL Verification study.

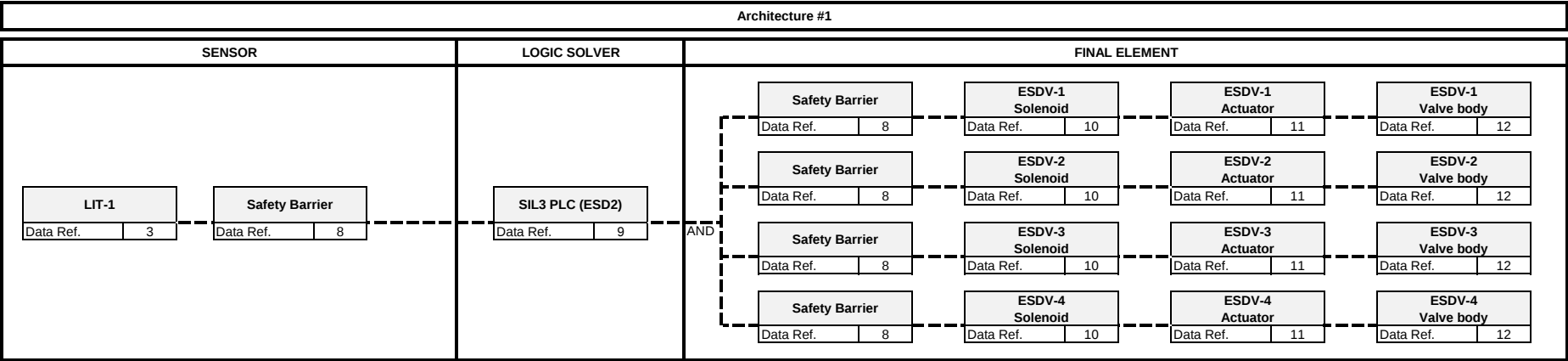
For each analysed safety function there are shown:

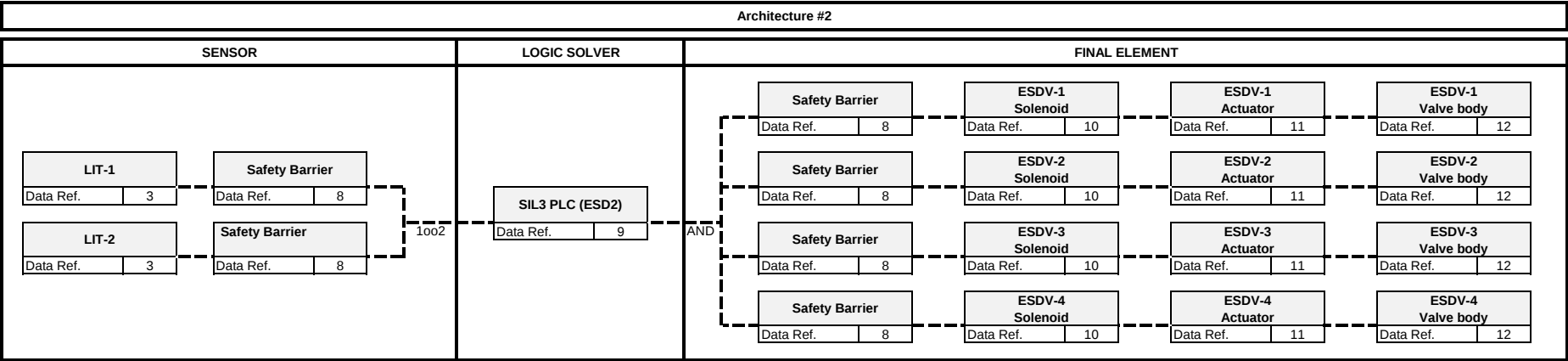
- the reference architecture among the types identified in the projects the SIF corresponds to;
- the required PFD from SIL Allocation study and the corresponding required SIL level;
- the calculated PFDavg and the corresponding calculated SIL level;
- the result of PFD and SIL level verification
- the result architectural requirements of SIF subcomponents verification

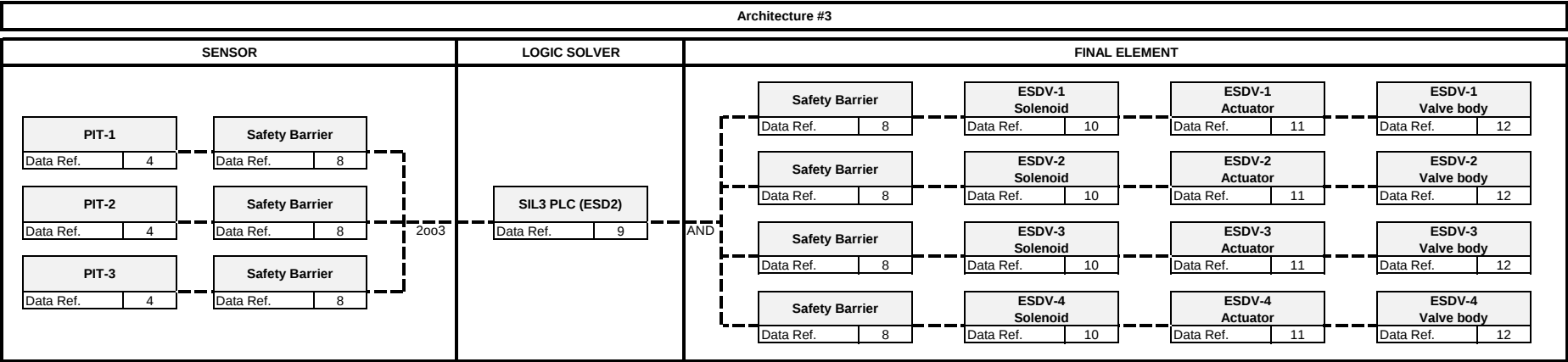
SIF #	TAG	Ref. Architecture #	Required PFD	Req. SIL level	Calc. PFD	Calc. SIL level	Verified	Arch. req. verified

	KPC Western Desert - EGYPT QASR COMPRESSION PROJECT SIL ALLOCATION STUDY	
Project n° 3538-200	DOCUMENT TITLE: SIL VERIFICATION REPORT DOCUMENT NUMBER: 13182I-006	Rev. No.: 0 September 2013

ATTACHMENT B - SIF ARCHITECTURES





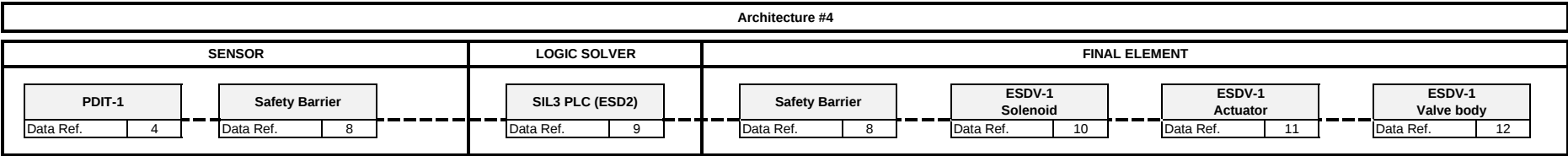


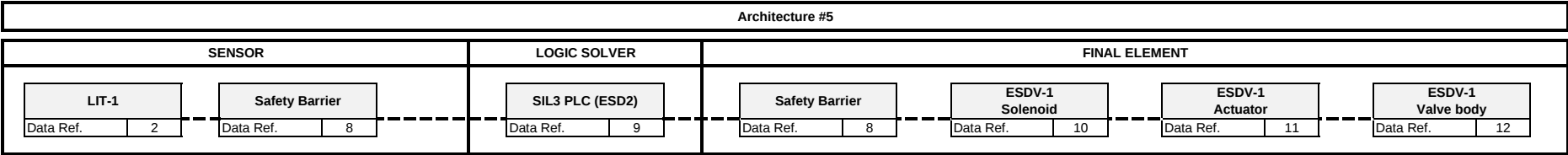
PIT-3

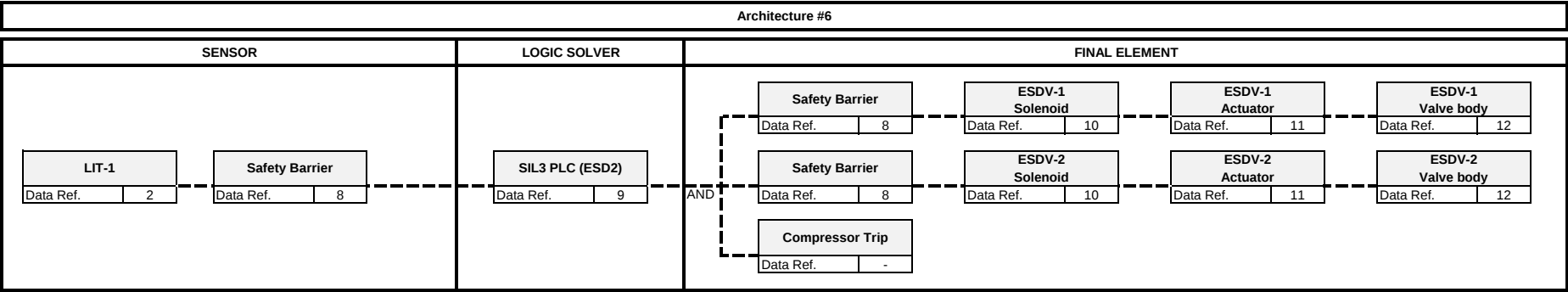
Data Ref. 4

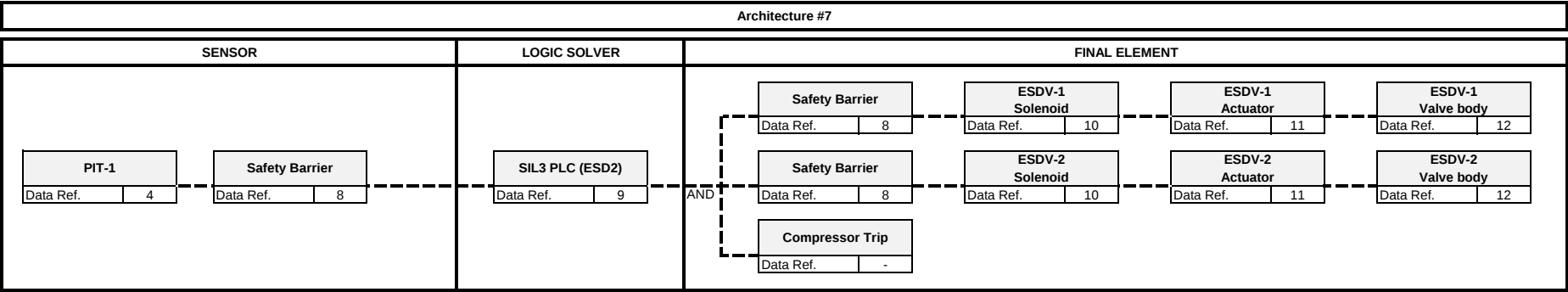
Safety Barrier

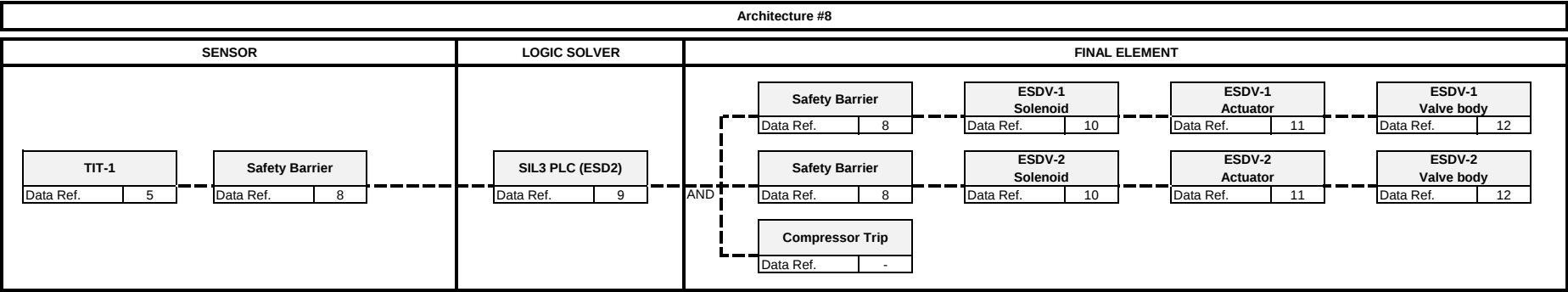
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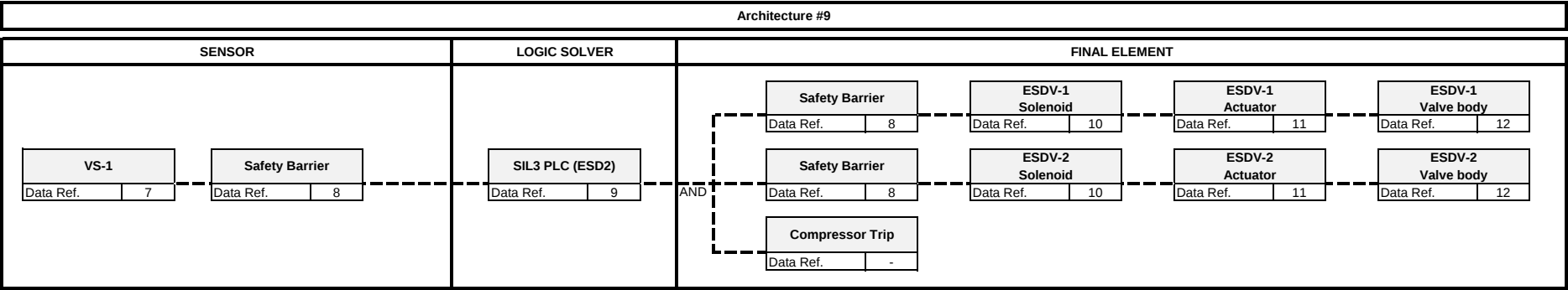


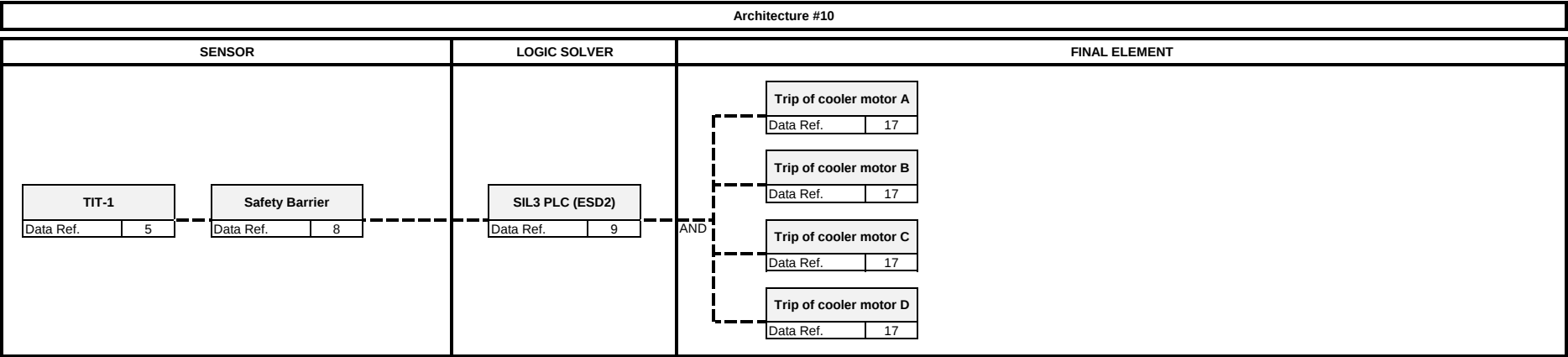


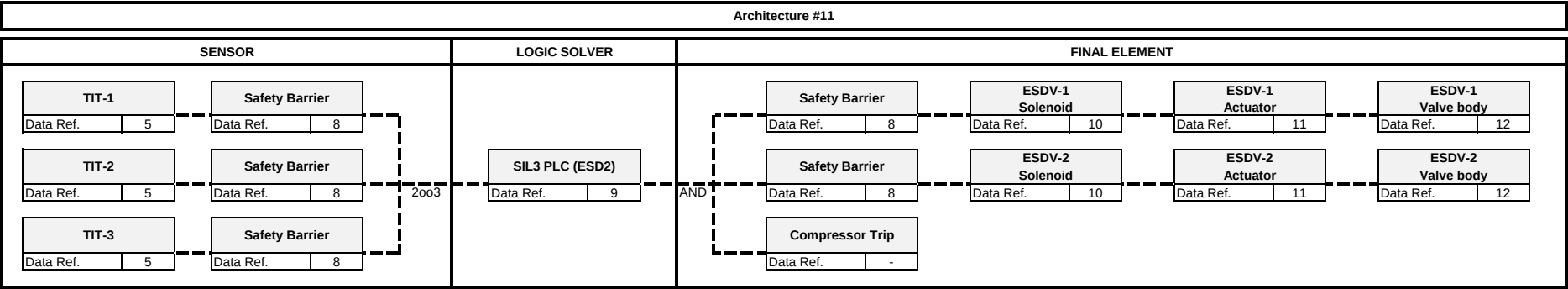


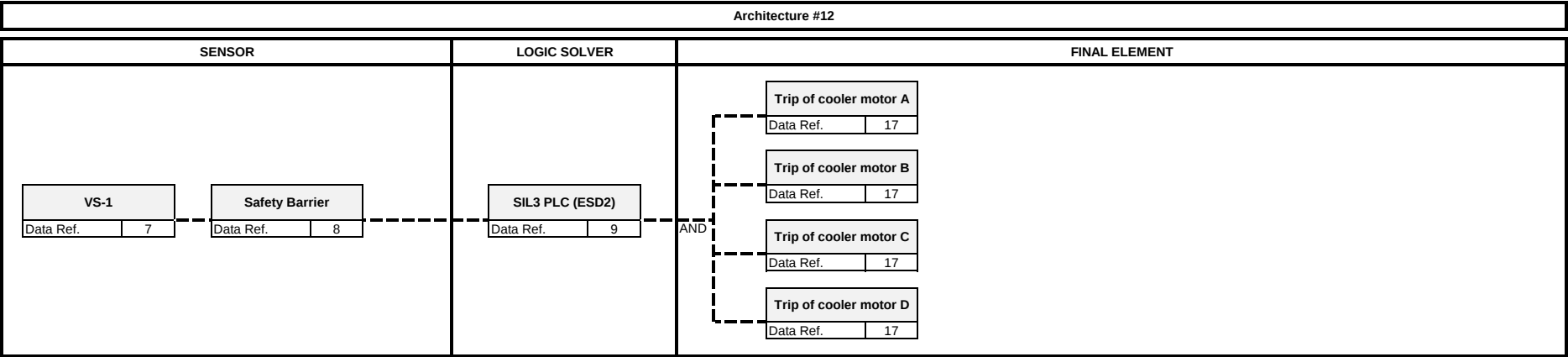


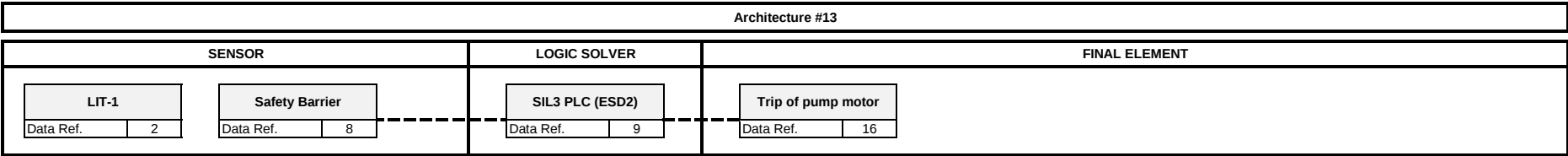


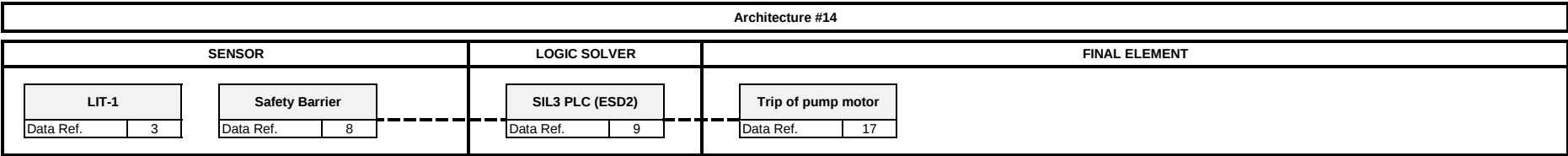


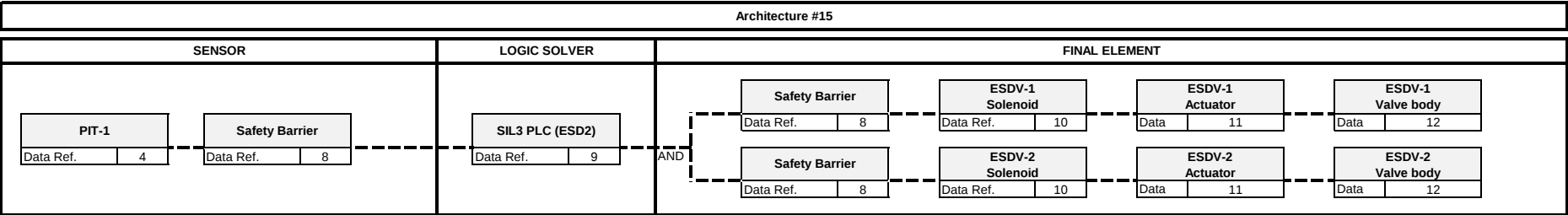












Safety Barrier

Data Ref.8

ESDV-2 Solenoid

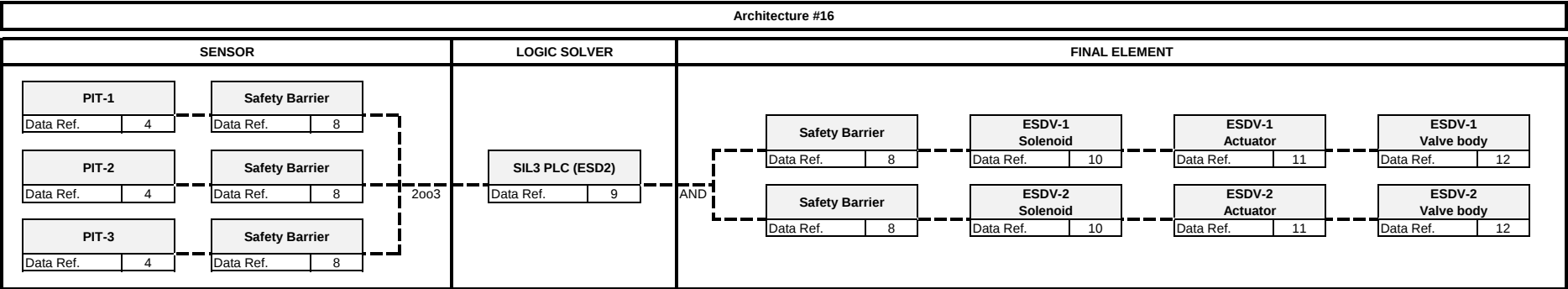
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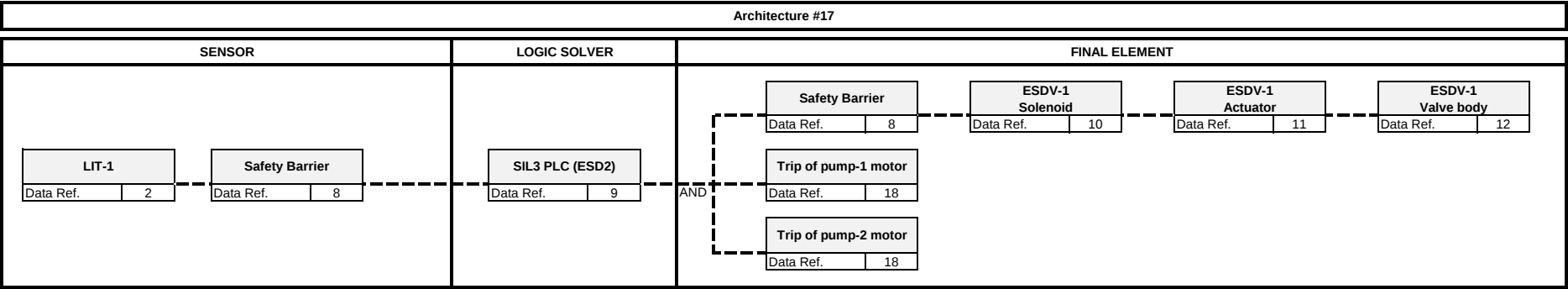
ESDV-2 Actuator

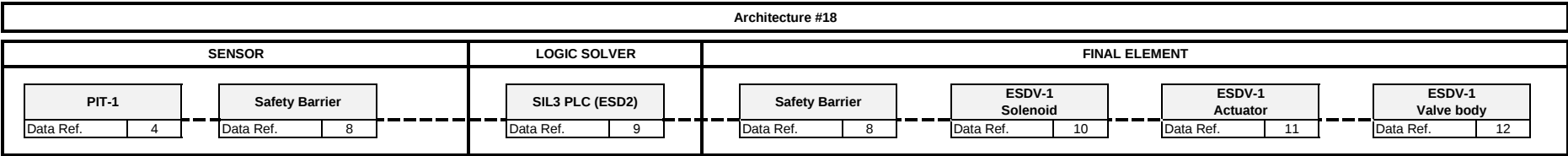
Data11

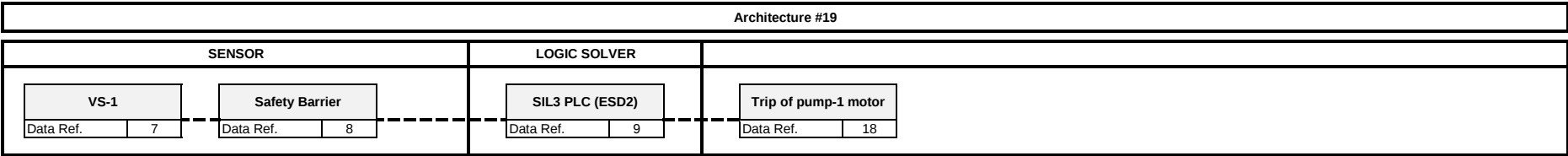
ESDV-2 Valve body

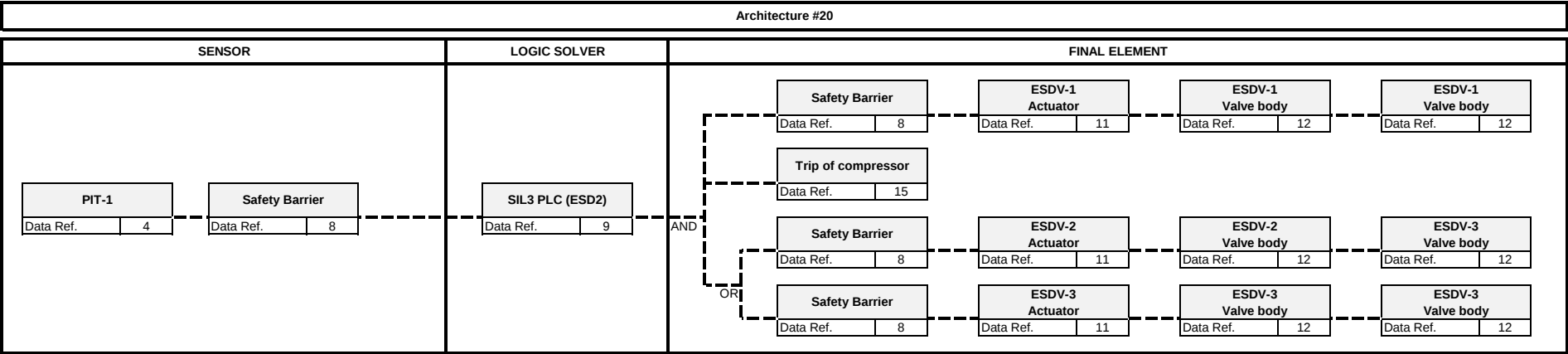
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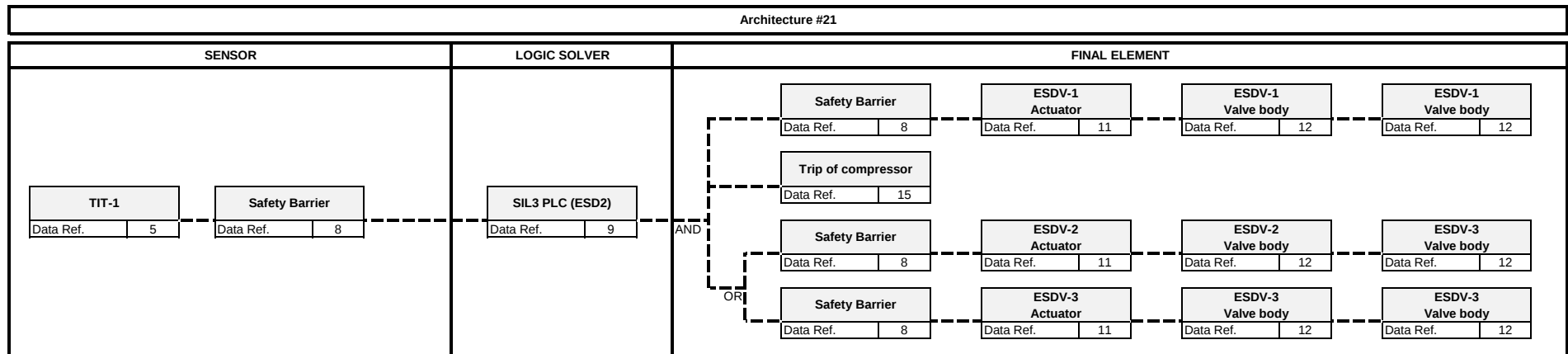


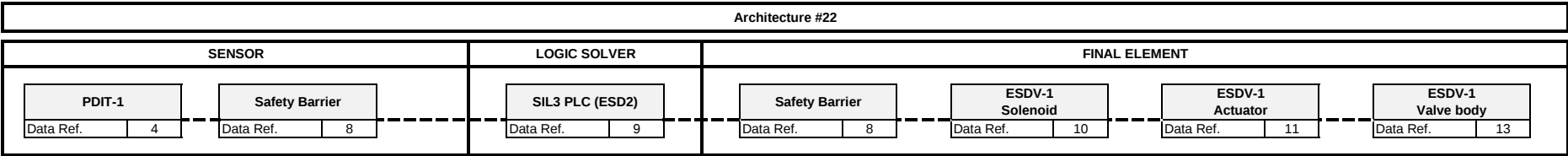


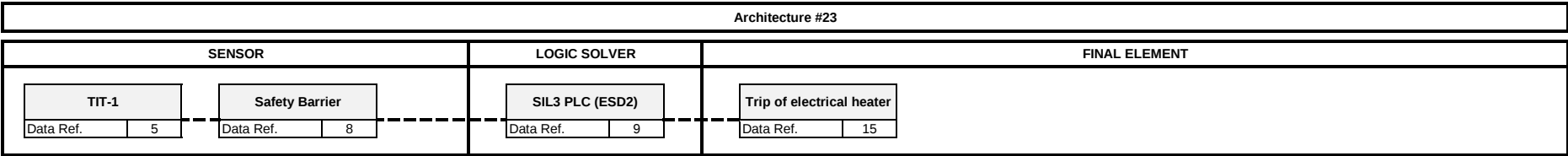


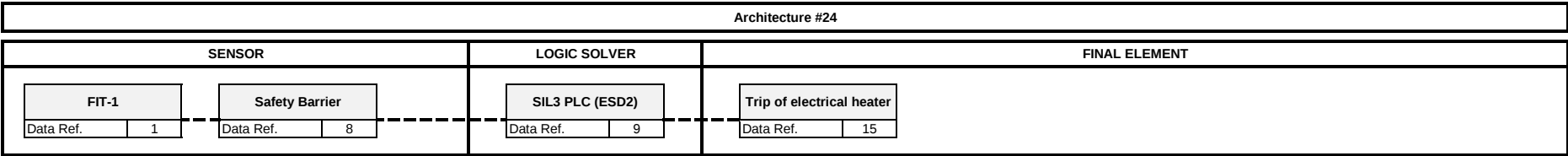


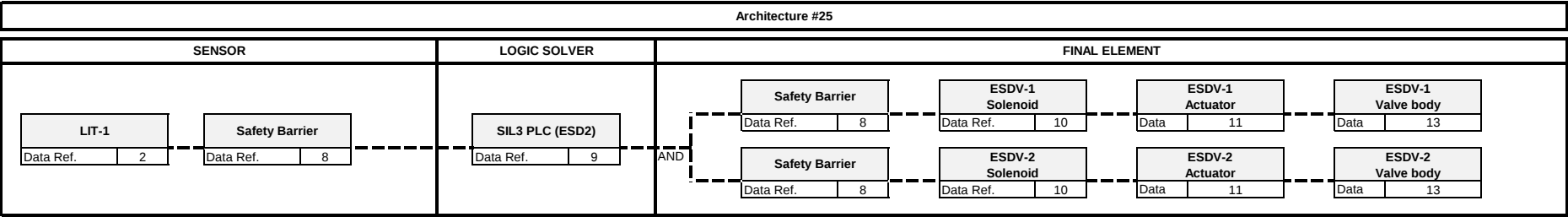


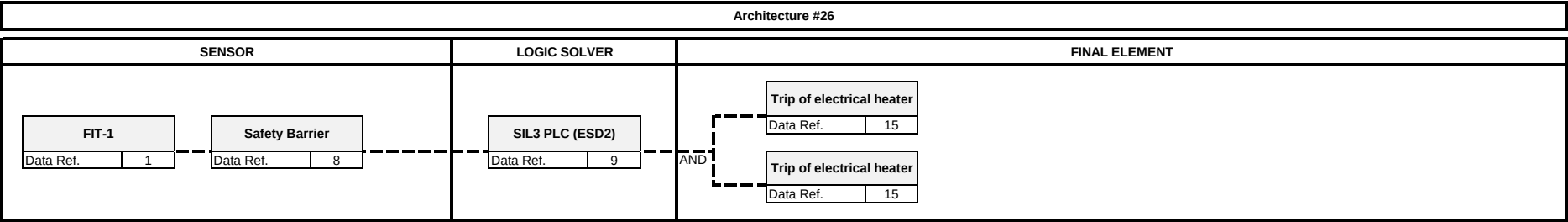


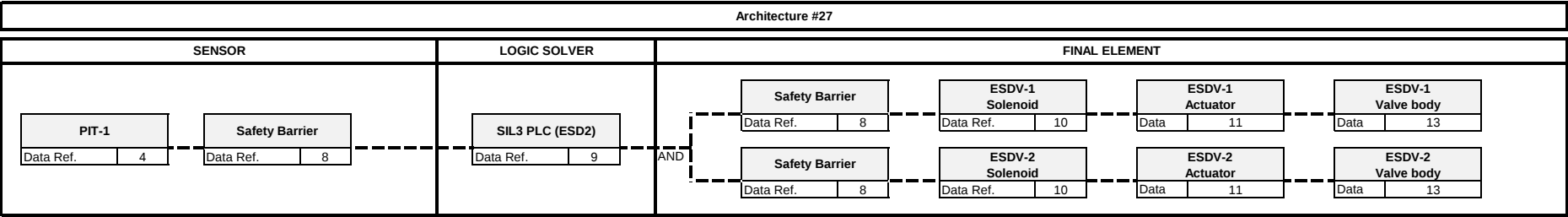












Safety Barrier

Data Ref.8

ESDV-2 Solenoid

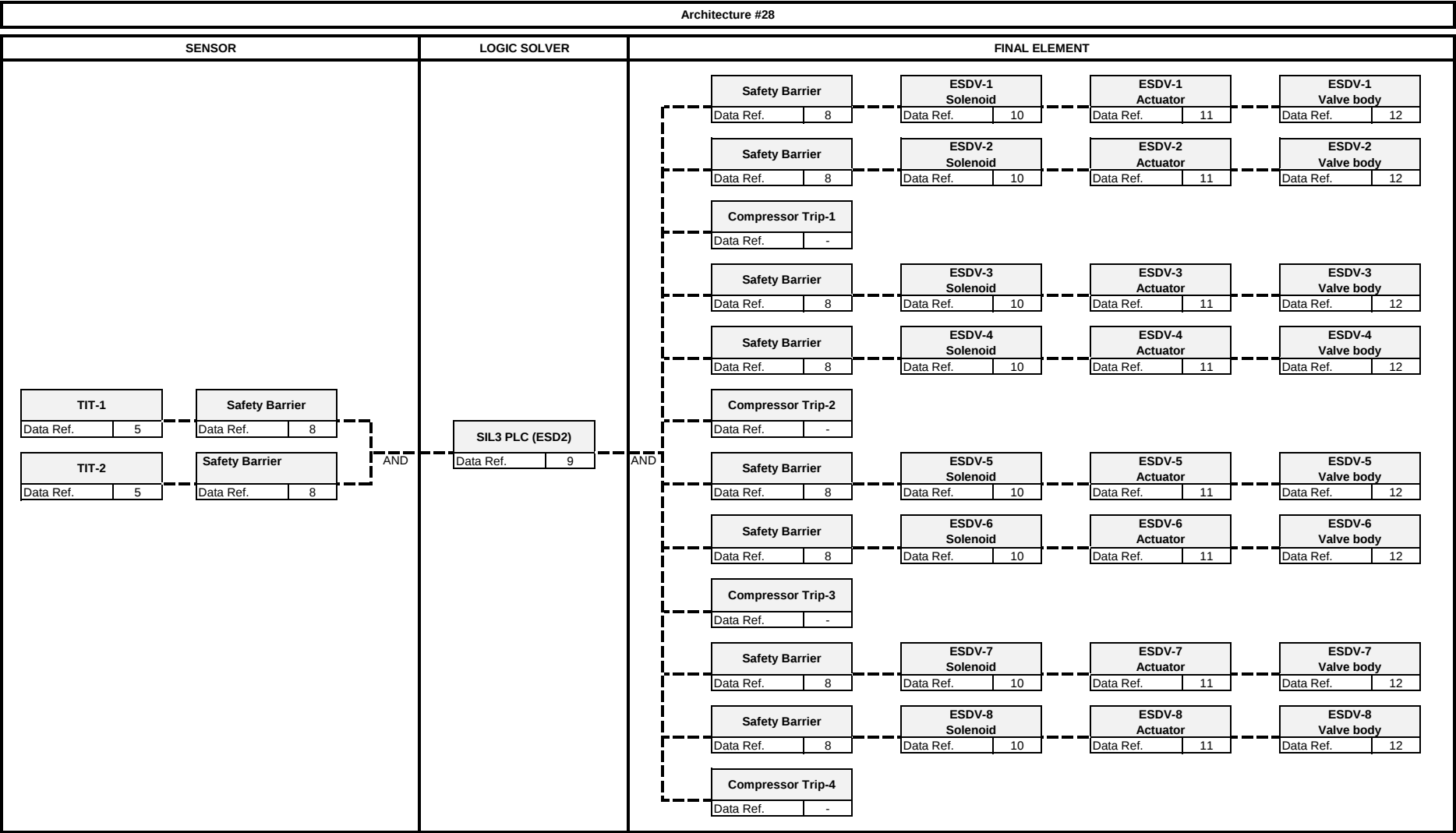
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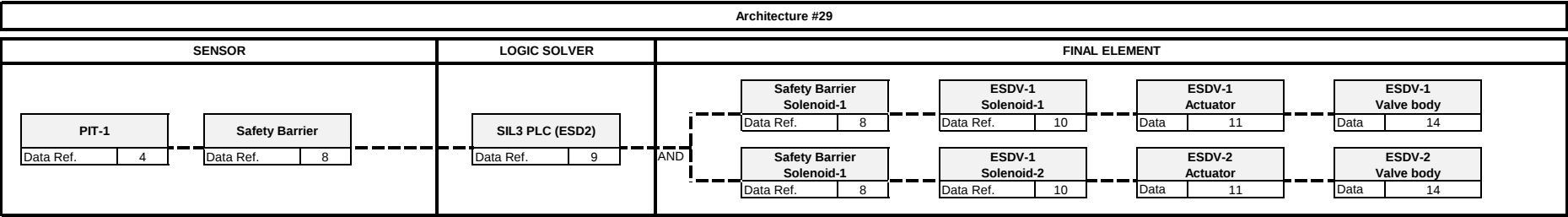
ESDV-2 Actuator

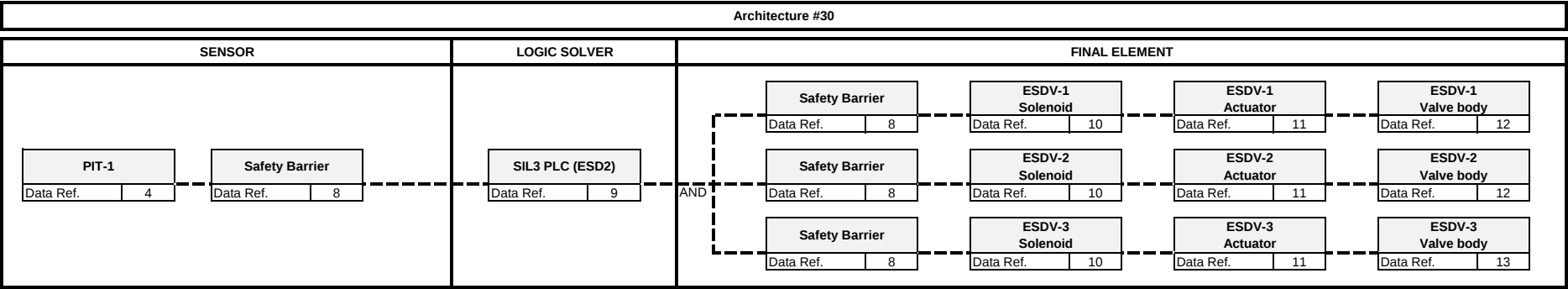
Data11

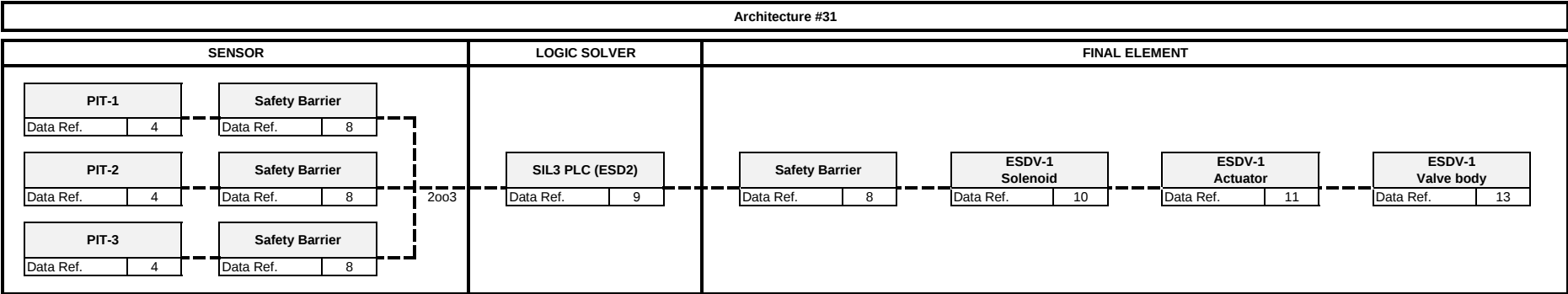
ESDV-2 Valve body

Data13









	KPC Western Desert - EGYPT QASR COMPRESSION PROJECT SIL ALLOCATION STUDY	
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ATTACHMENT C – RELIABILITY DATA

SIF #	Description	Vendor	Model	Lambda-SD (fit)	Lambda-SU (fit)	Lambda Res. (fit)	Lambda-DD (fit)	Lambda-DU (fit)	Beta (5% lambda-DU) (fit)	SFF (%)	Test Interval (hours)	MTTR (hours)	PVST interval (hours)	PFDavg	PFH / hour	Source
1	Flow measurement (DP)		Generic EXIDA	0	2400	0	0	3600	180	40	8760	---	---			EXIDA 1.4.1
2	Level measurement (displacement)		Generic EXIDA	0	0	0	0	1250	62,5	58,3	8760	---	---	---	---	EXIDA 1.5.2
3	Level measurement (radar)		Generic EXIDA	0	0	200	0	500	25	72,2	8760	---	---	---	---	EXIDA 1.5.4
4	Pressure measurement (generic)		Generic EXIDA	0	0	200	0	600	30	60	8760	---	---			EXIDA 1.6.2
5	Temperature measurement (generic)		Generic EXIDA	0	0	100	0	300	15	62,5	8760	---	---			EXIDA 1.8.2
6	Vibration (Piezoelectric)		Generic EXIDA	0	0	0	0	20000	---	20	---	---	---	---	---	EXIDA 1.9.3
7	Vibration (Magnetic)		Generic EXIDA	0	0	0	0	160	---	20	---	---	---	---	---	EXIDA 1.9.2
8	Safety Barrier		Generic EXIDA	0	650	0	0	350	17,5	65	8760	---	---	---	---	EXIDA 2.1.2
SUPERSEE DED	Generic SIL 3 PLC (main processor, analog in, analog out)		Generic EXIDA	9888	163	0	3893	258	---	suitable for SIL 3	8760	8	---	---	---	EXIDA 2.3.4
9	ESD PLC	GE	FANUC GMR series 90-70 PLC with Genius Block I/O's	---	---	---	---	---	1%*	suitable for SIL required	4380*	8*	---	1,525E-04**	---	Vendor data (GE Fanuc Manuals Genius GFK-1649)
10	Solenoid Valve		Generic EXIDA	0	1010	500	0	585	29,25	72,1	---	---	---	---	---	EXIDA 3.1.2
11	SDV valve (actuator)		Generic EXIDA. PVST	300	0	0	350	320	---	67	8760	8	1440	----	---	EXIDA 3.3.2
12	SDV valve (body)		Generic EXIDA. Clean service.	0	0	0	400	1200	---	25	8760	8	1440	---	---	EXIDA 3.4.1
13	SDV valve (body)		Generic EXIDA. Clean service.	0	0	0	400	400	---	50	8760	8	1440	---	---	EXIDA 3.4.1
14	SDV valve (body)		Generic EXIDA. Clean service.	0	0	0	400	200	---	66,7	8760	8	1440	---	---	EXIDA 3.4.1
15	Relay		Generic EXIDA	0	900	0	0	600	---	60	8760	---	---	---	---	EXIDA 3.7.8
16	MCC stop		Generic EXIDA (1 to 7,5 kW)	0	1000	0	0	620	---	61,7	8760	---	---	---	---	EXIDA 3.7.4
17	MCC stop		Generic EXIDA (7,5 to 75 kW)	0	1200	0	0	720	---	62,5	8760	---	---	---	---	EXIDA 3.7.4
18	MCC stop		Generic EXIDA (75 to 186 kW)	0	1400	0	0	820	---	63,1	8760	---	---	---	---	EXIDA 3.7.4

Vendor data

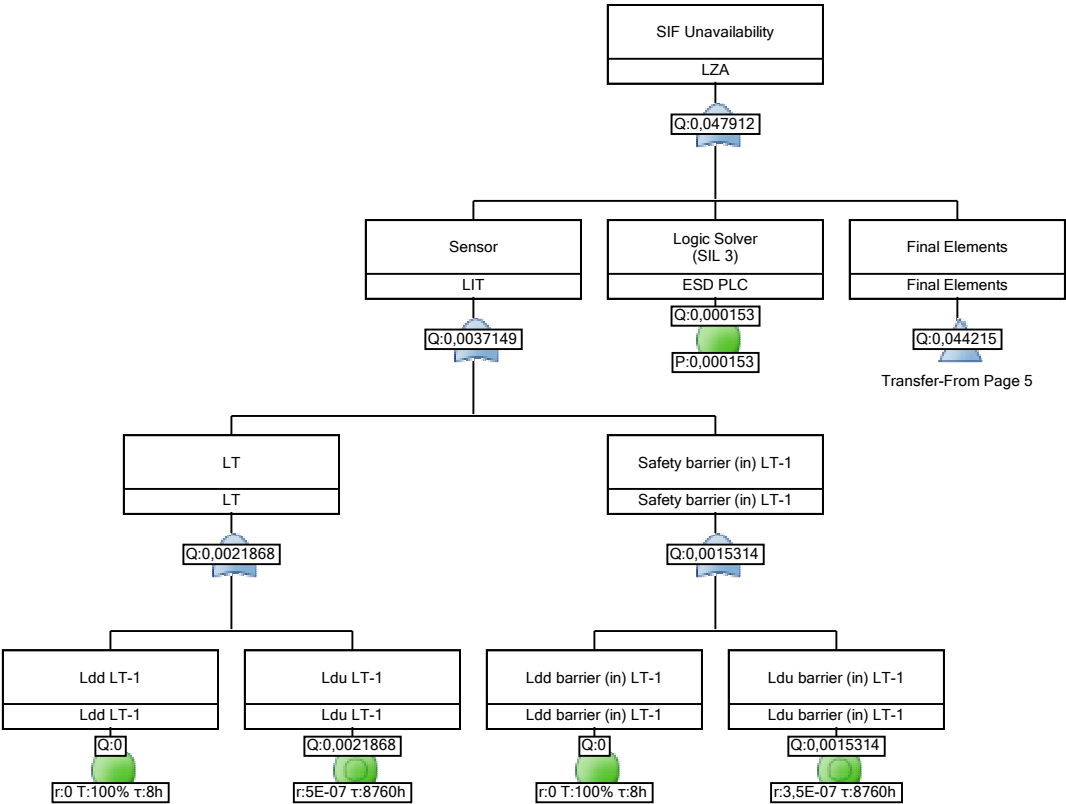
Exida - Specific data

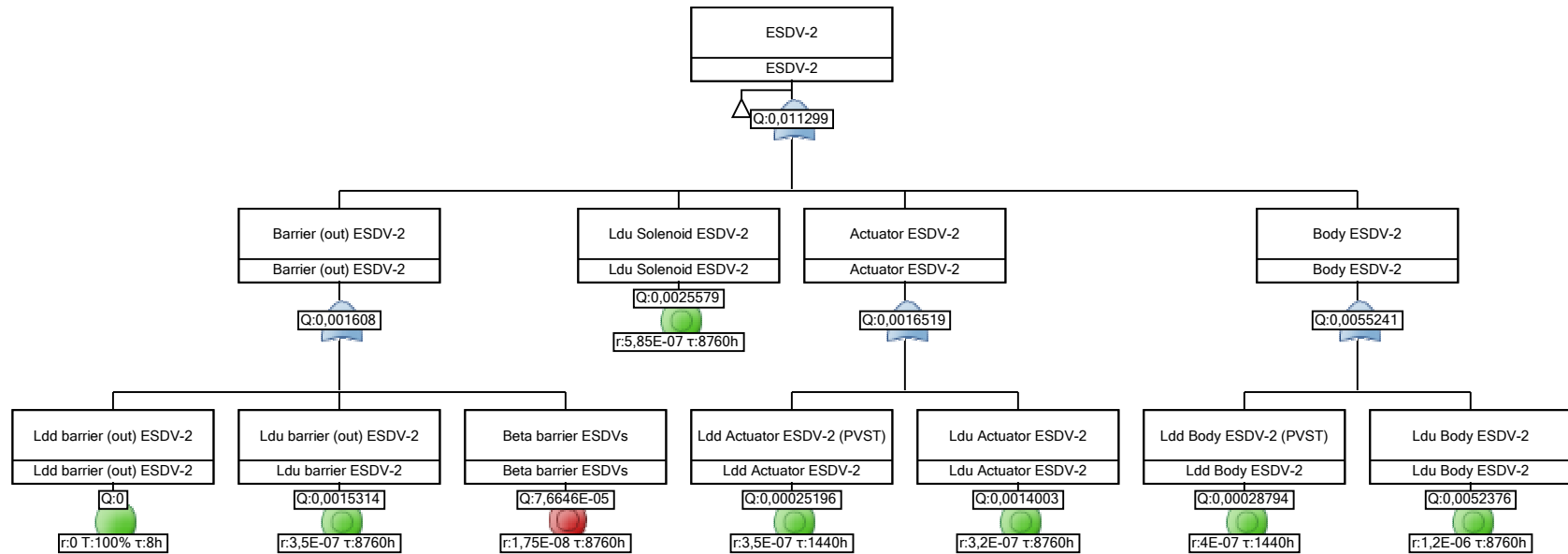
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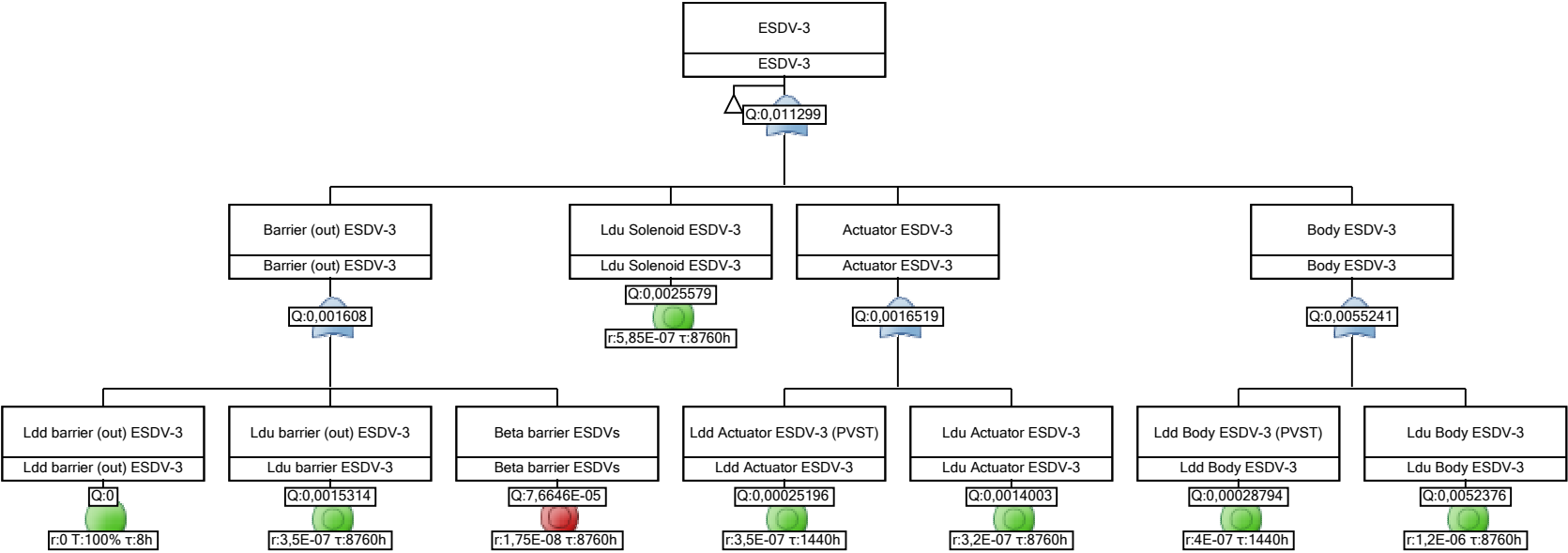
Other sources

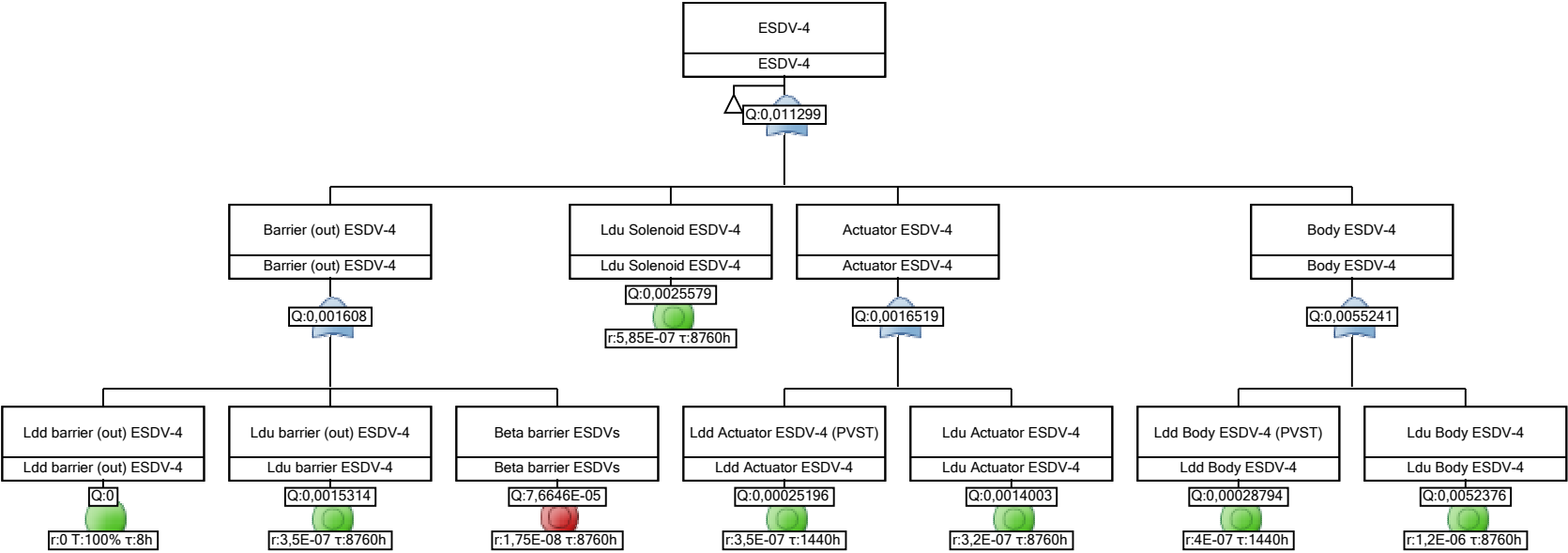
	KPC Western Desert - EGYPT QASR COMPRESSION PROJECT SIL ALLOCATION STUDY	
Project n° 3538-200	DOCUMENT TITLE: SIL VERIFICATION REPORT DOCUMENT NUMBER: 13182I-006	Rev. No.: 0 September 2013

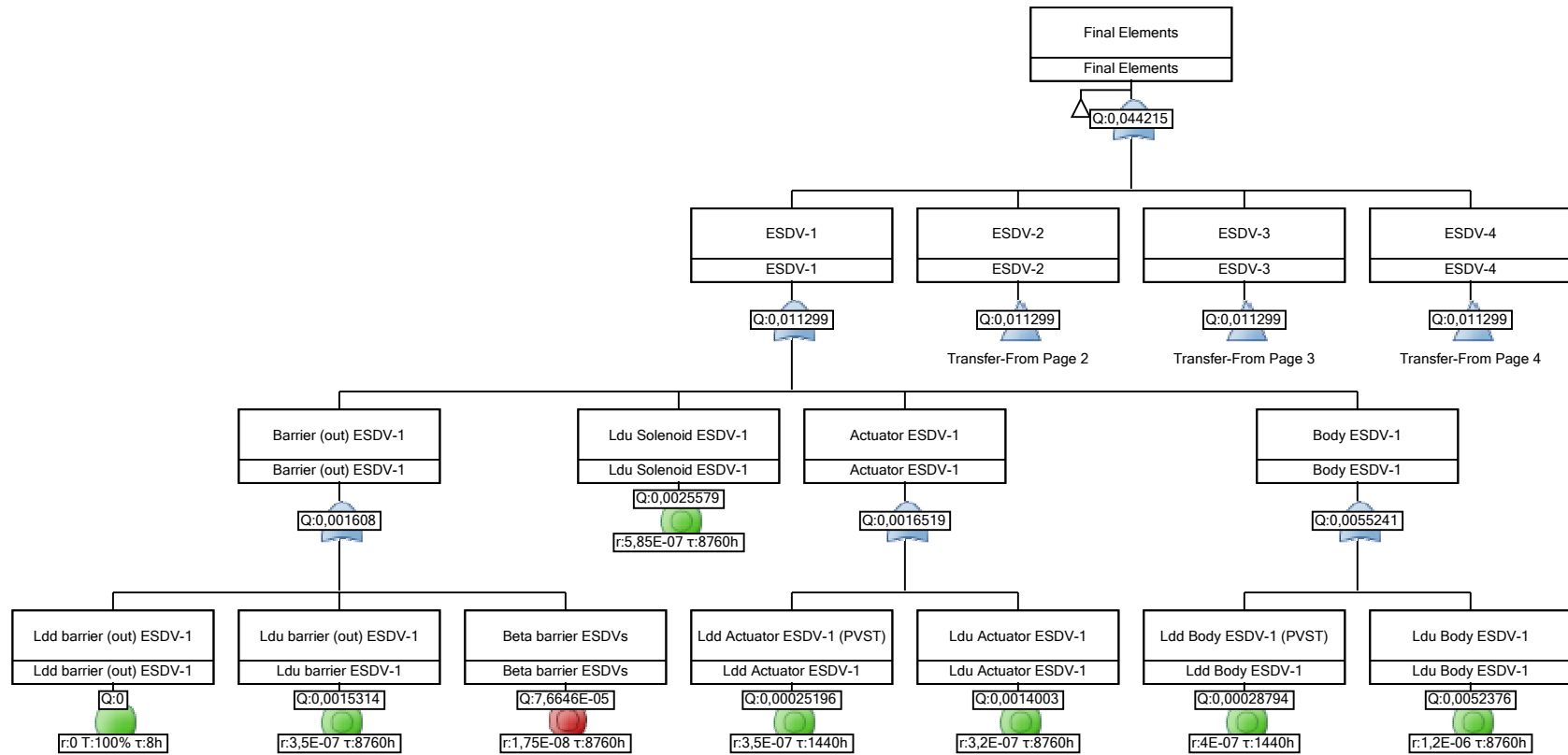
ATTACHMENT D – PFD CALCULATION BY FTA

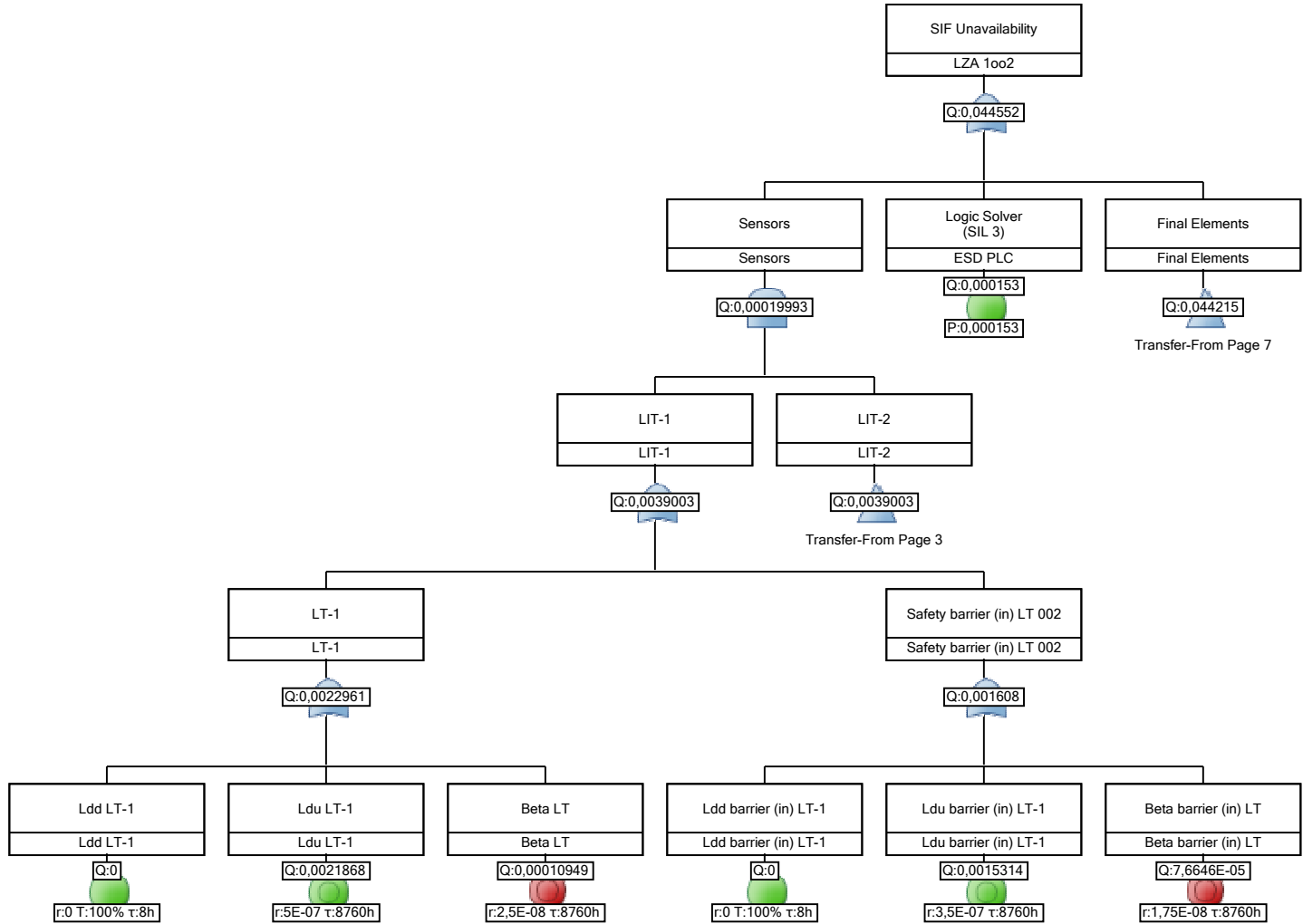


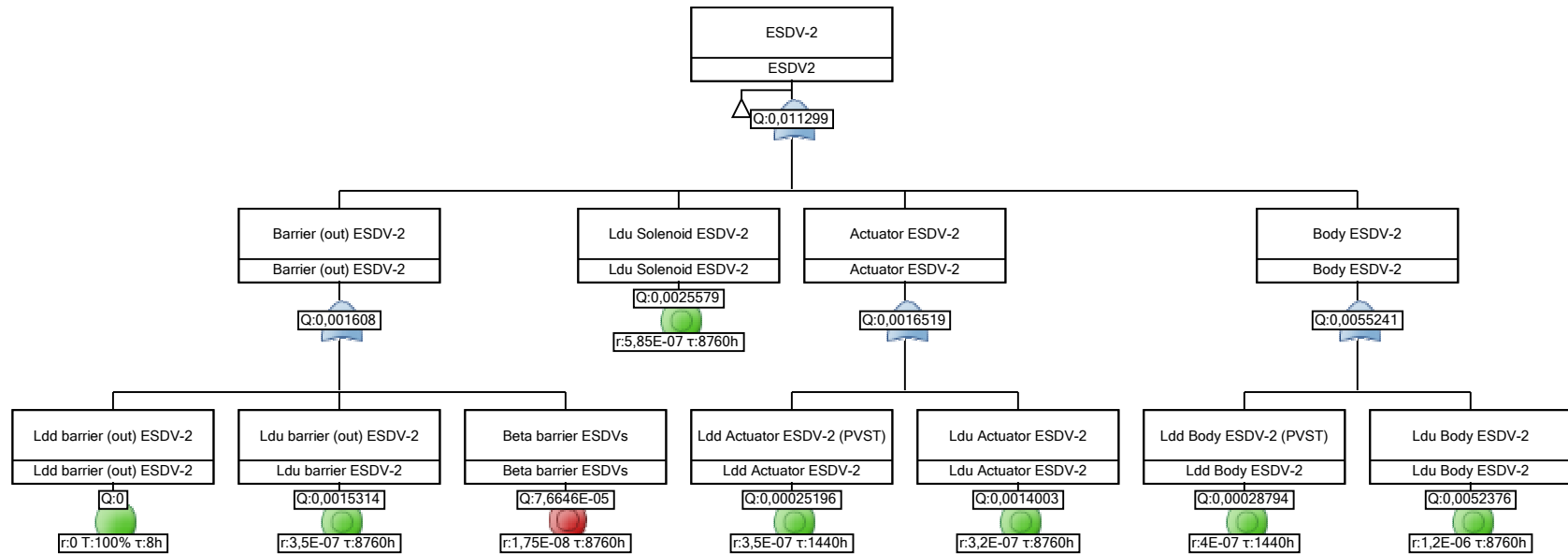


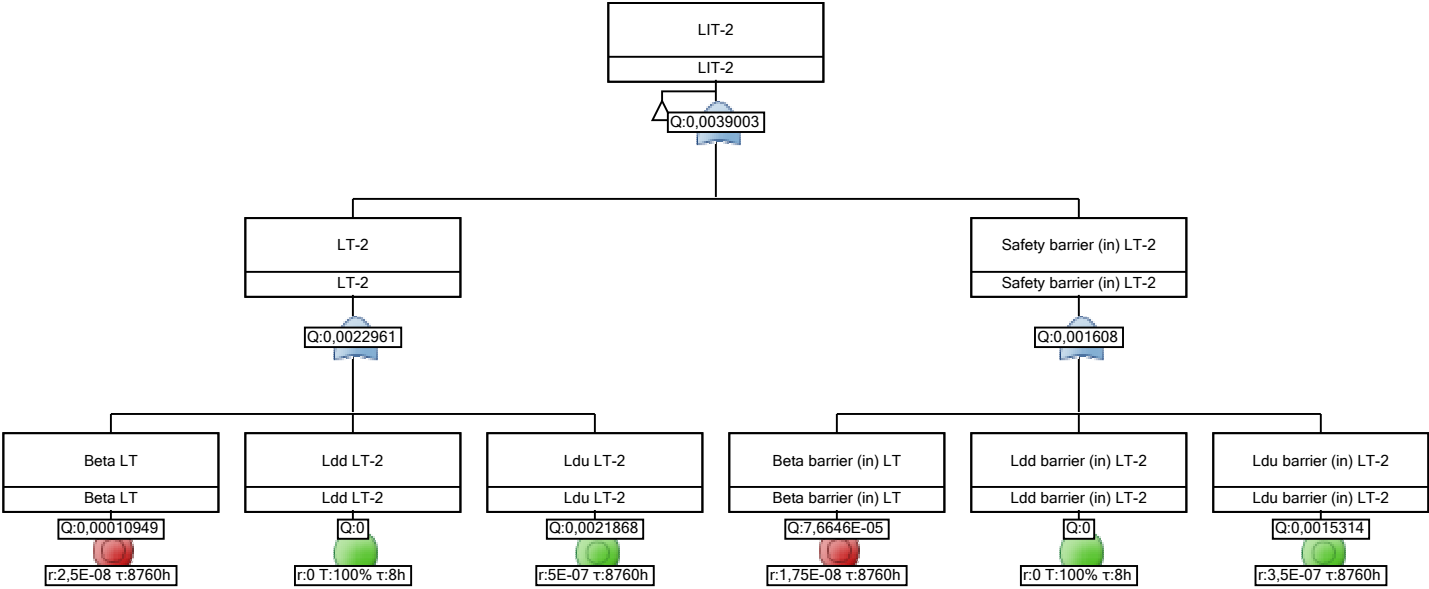




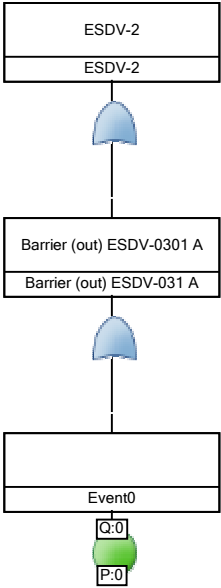


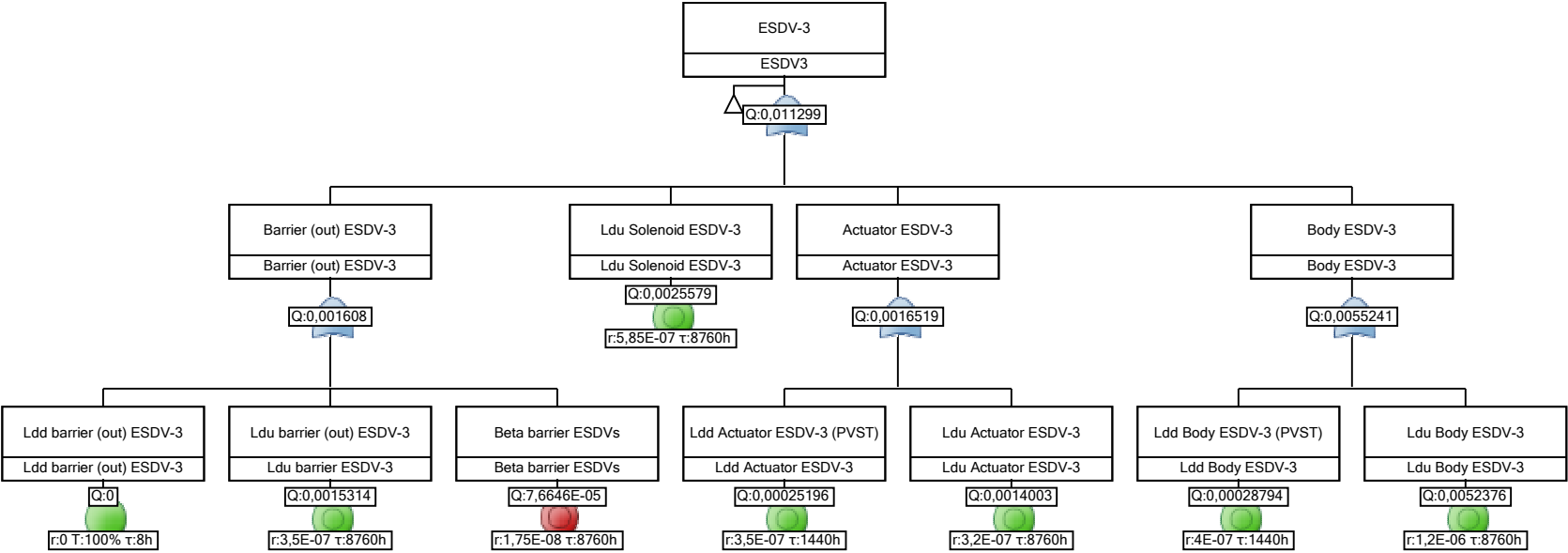


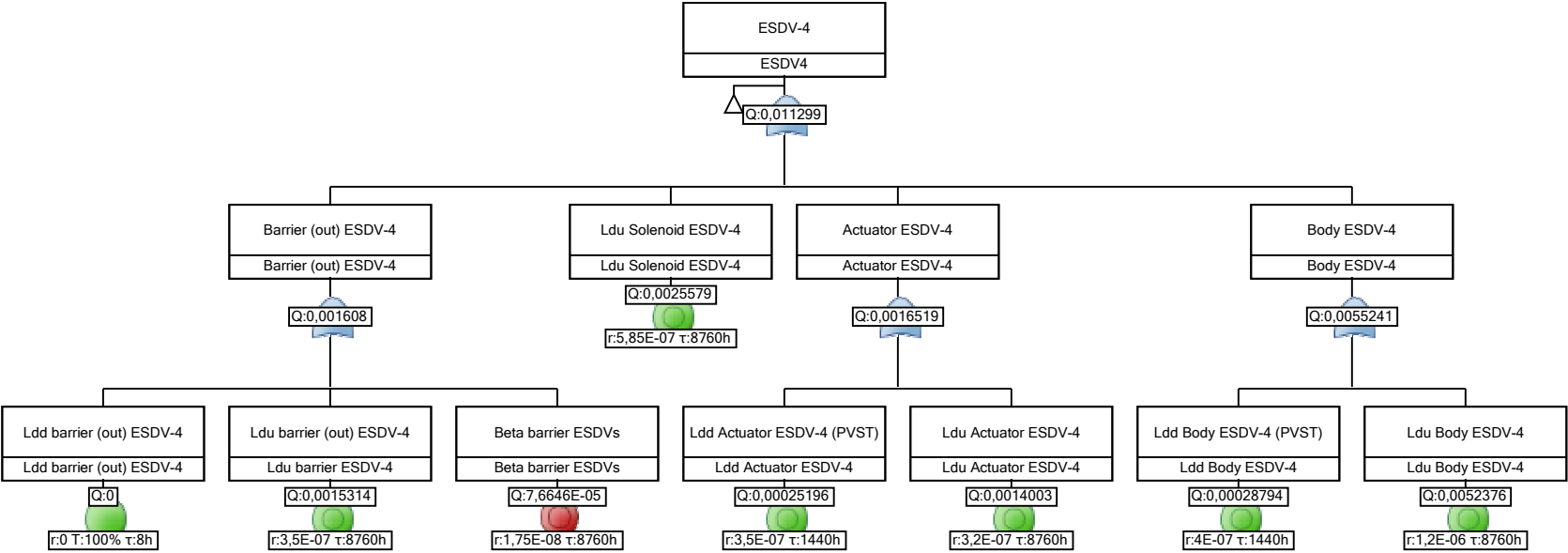


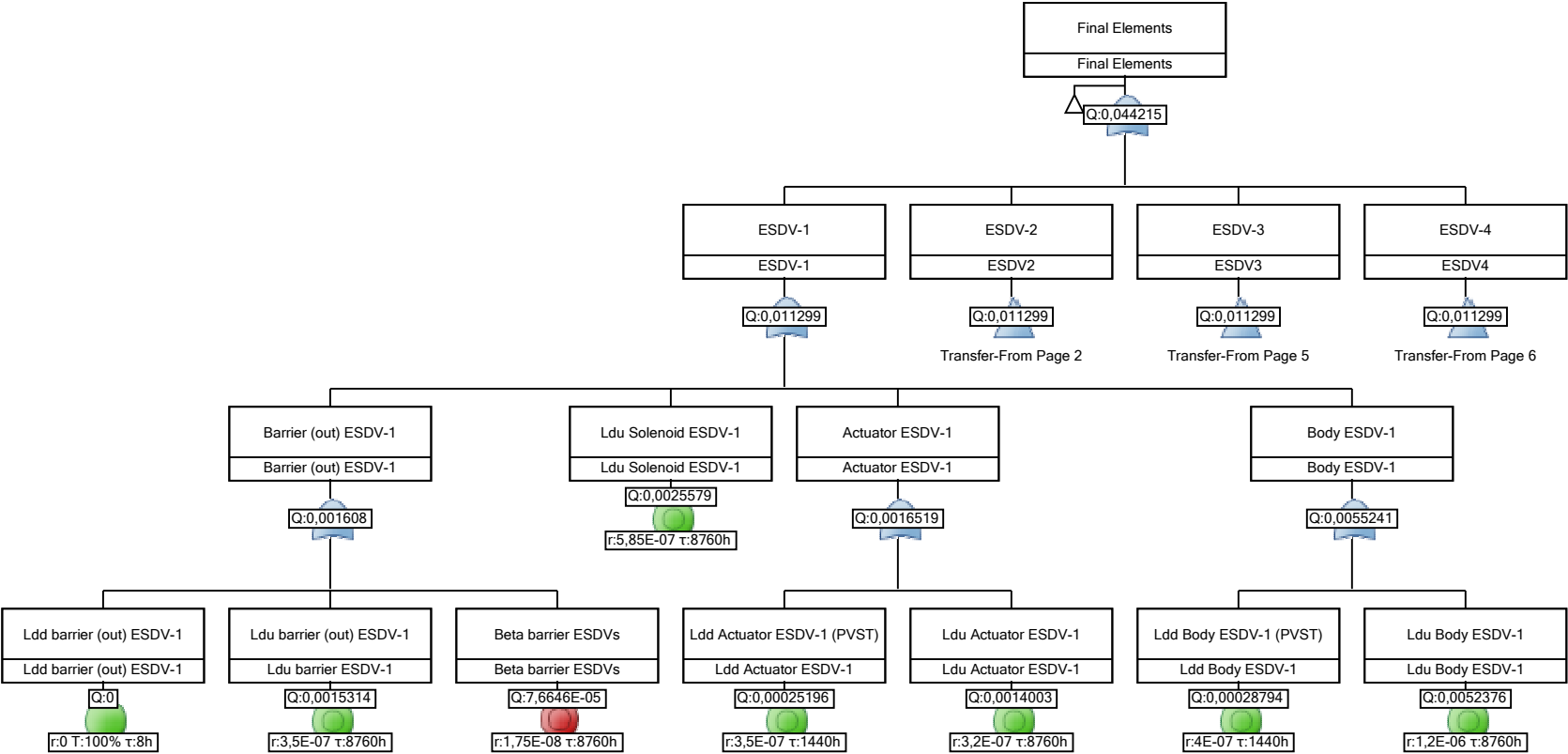


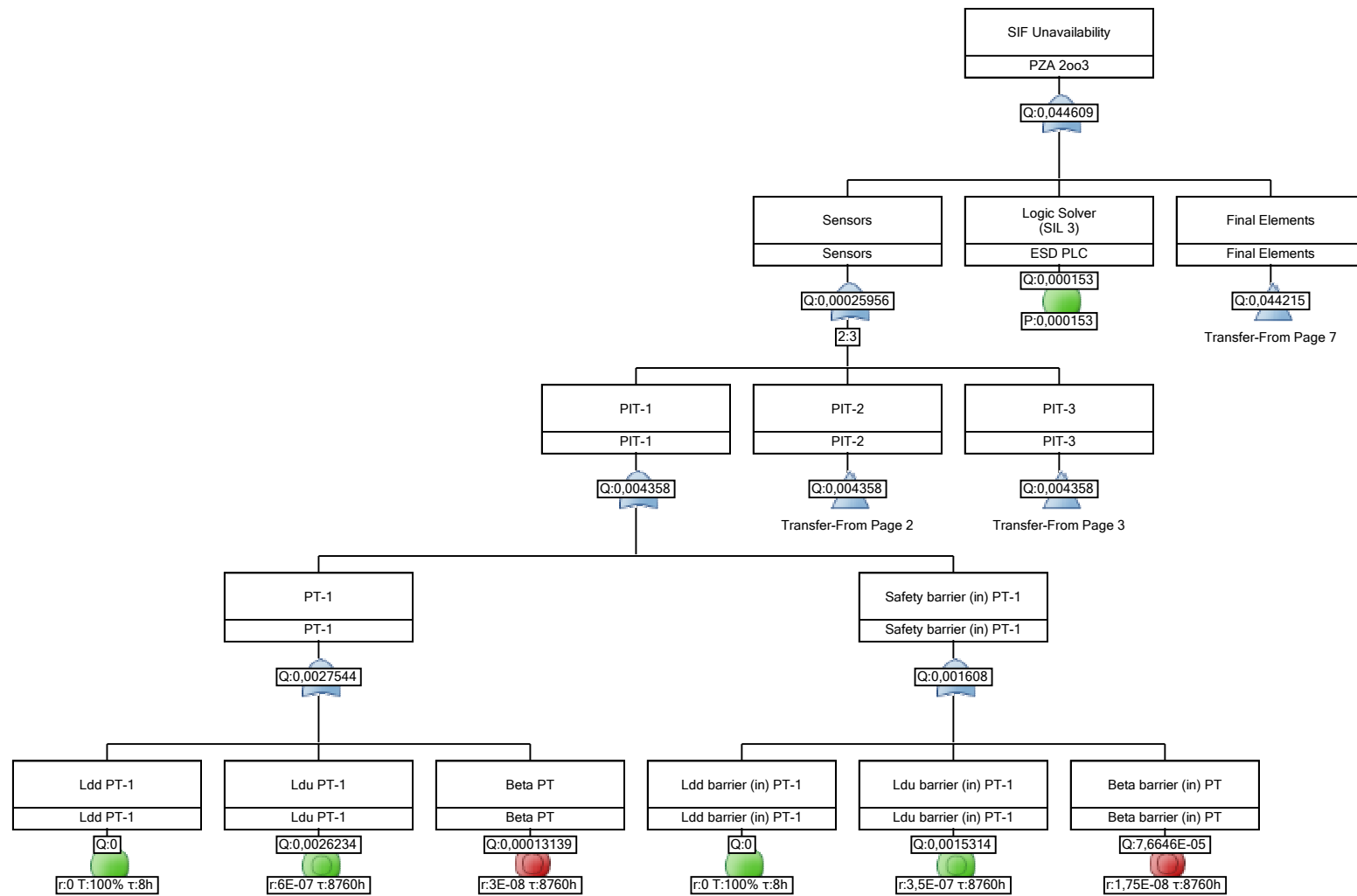
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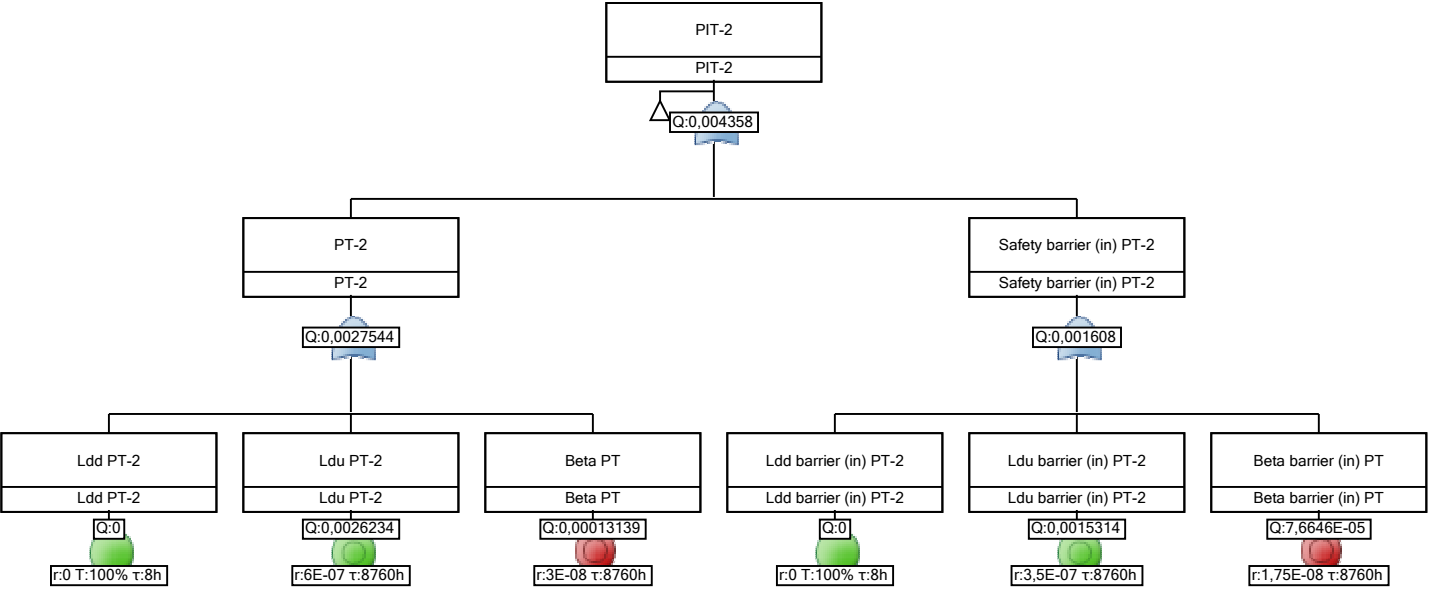




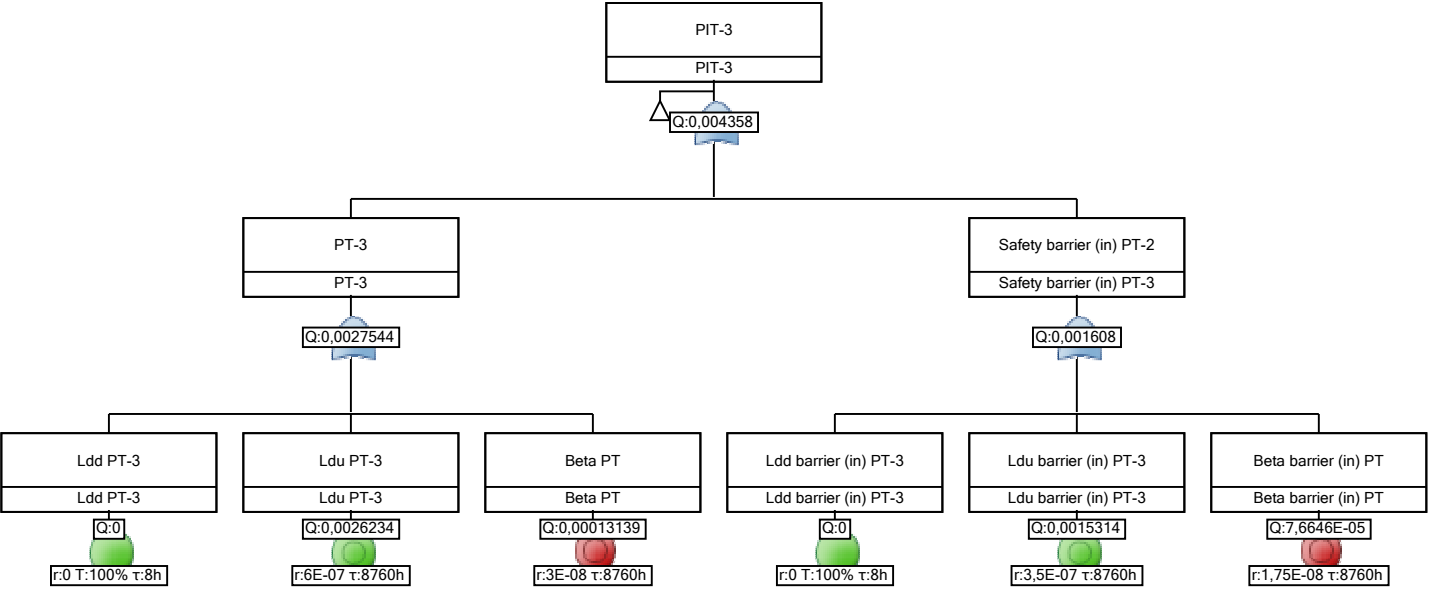


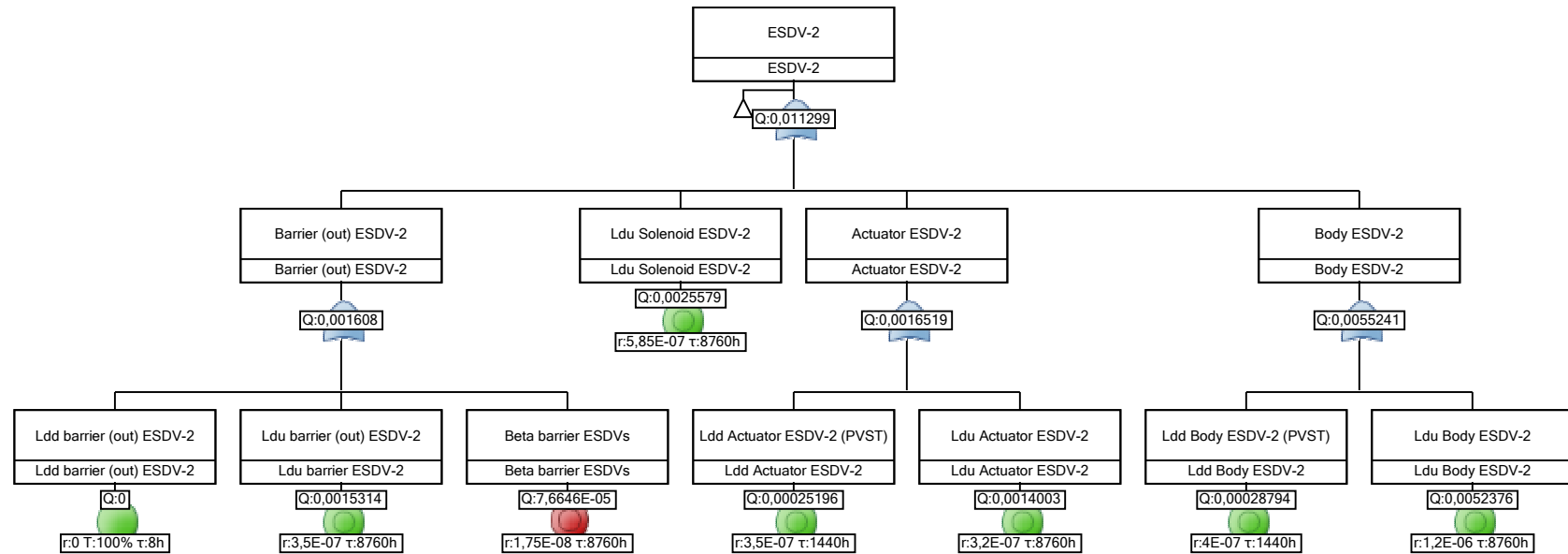


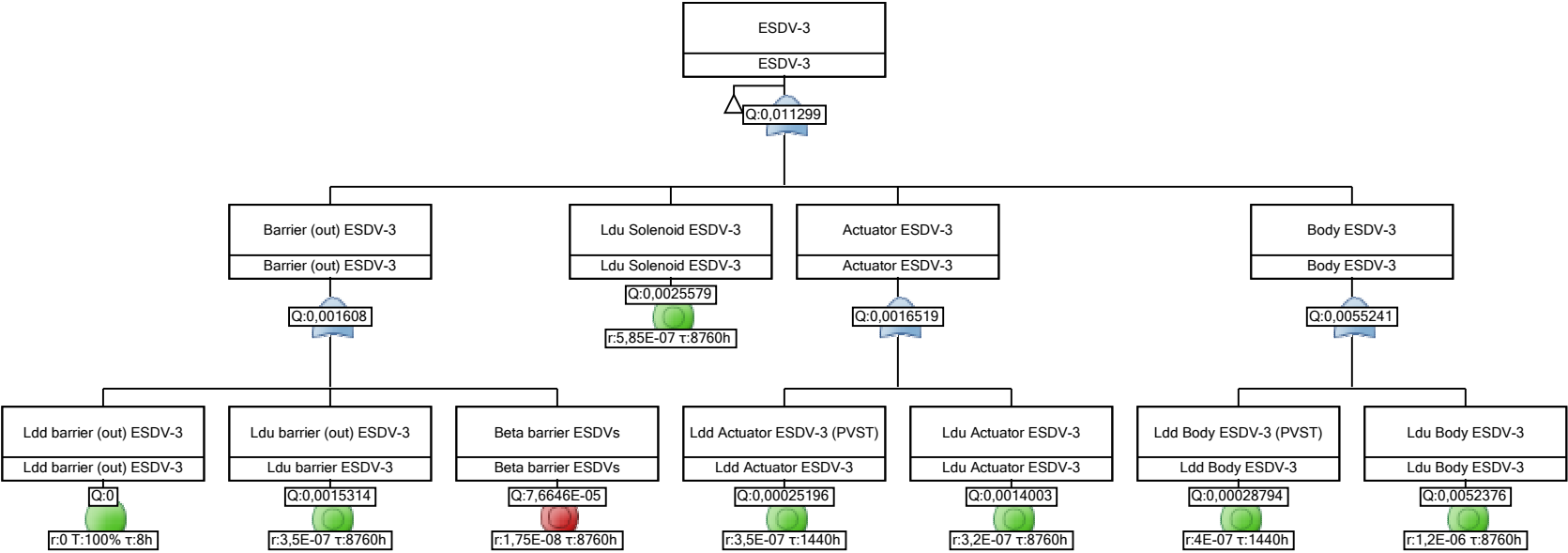
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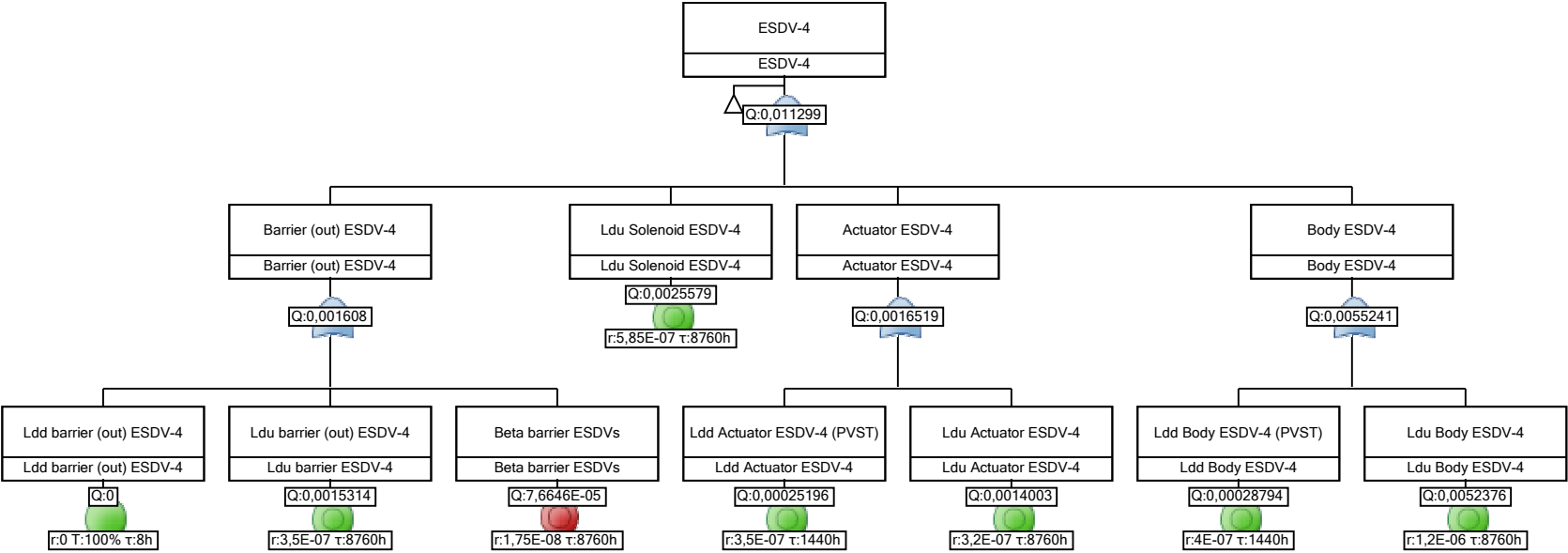


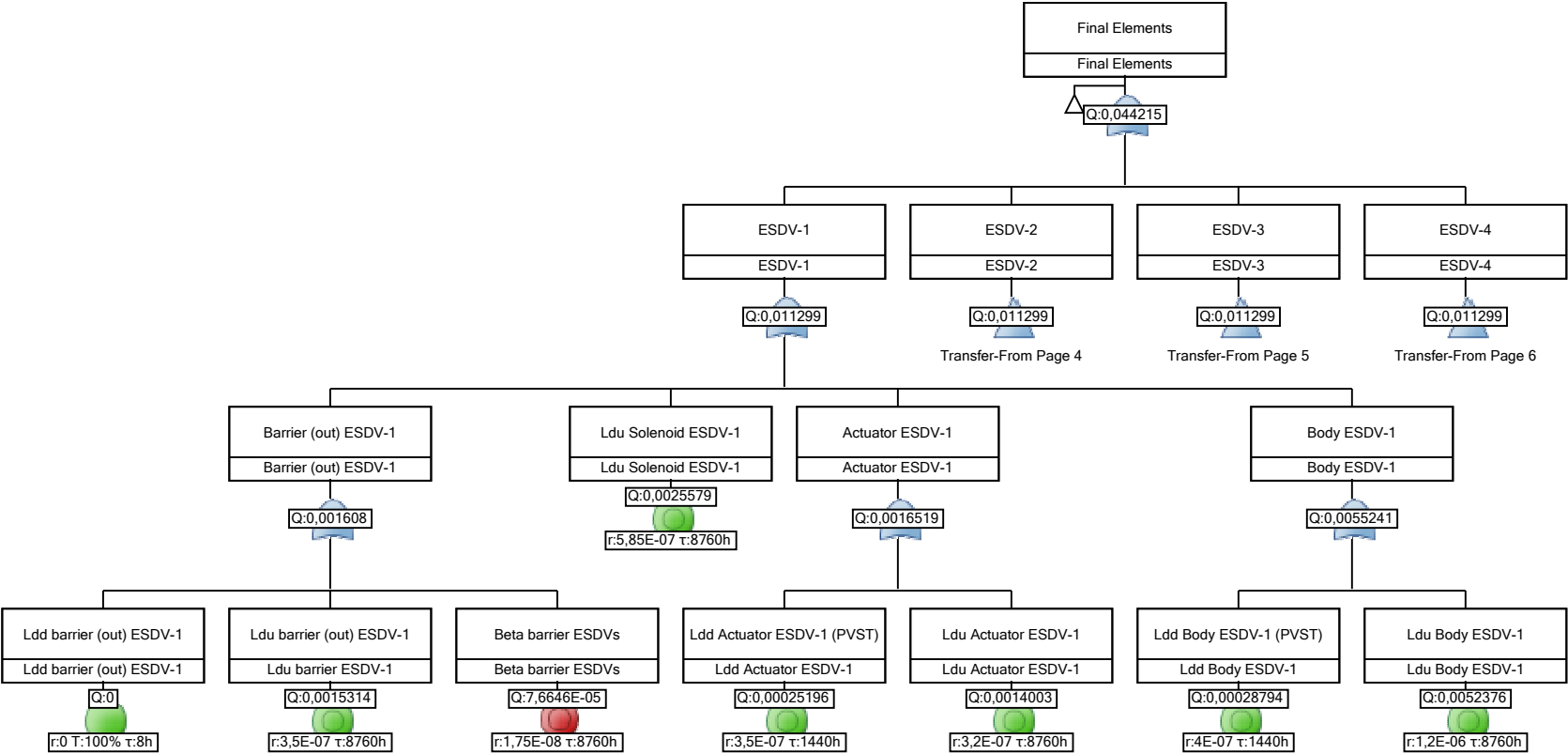
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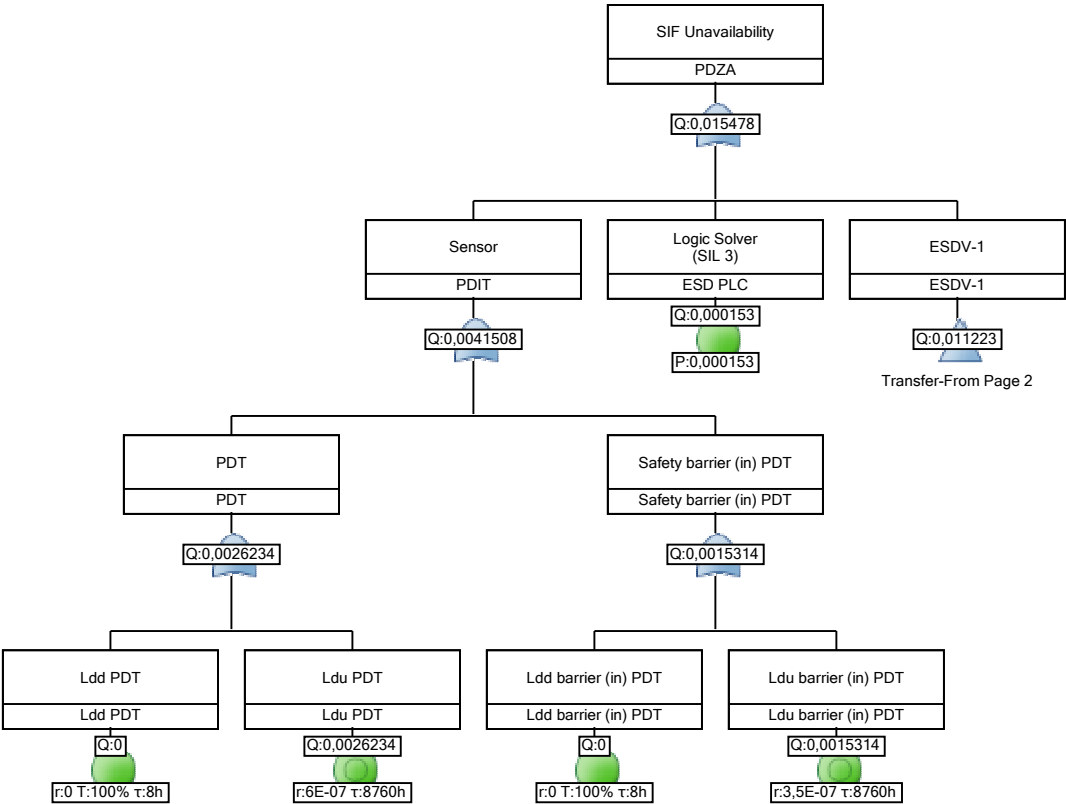




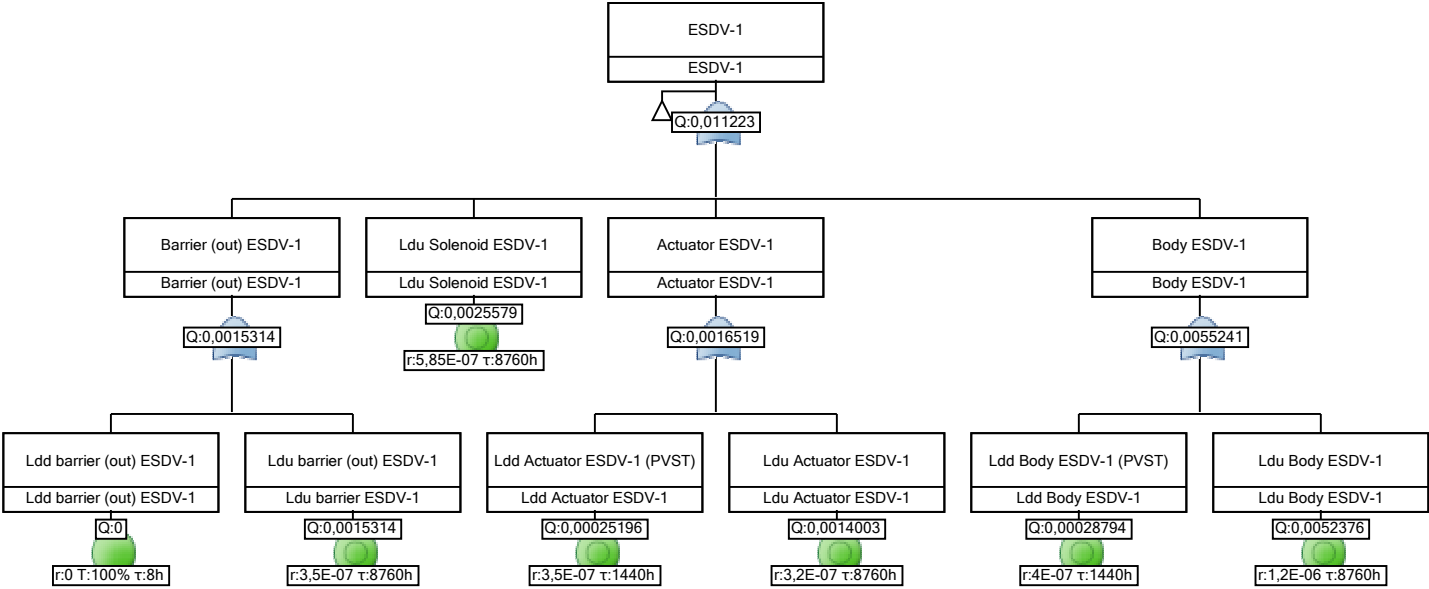


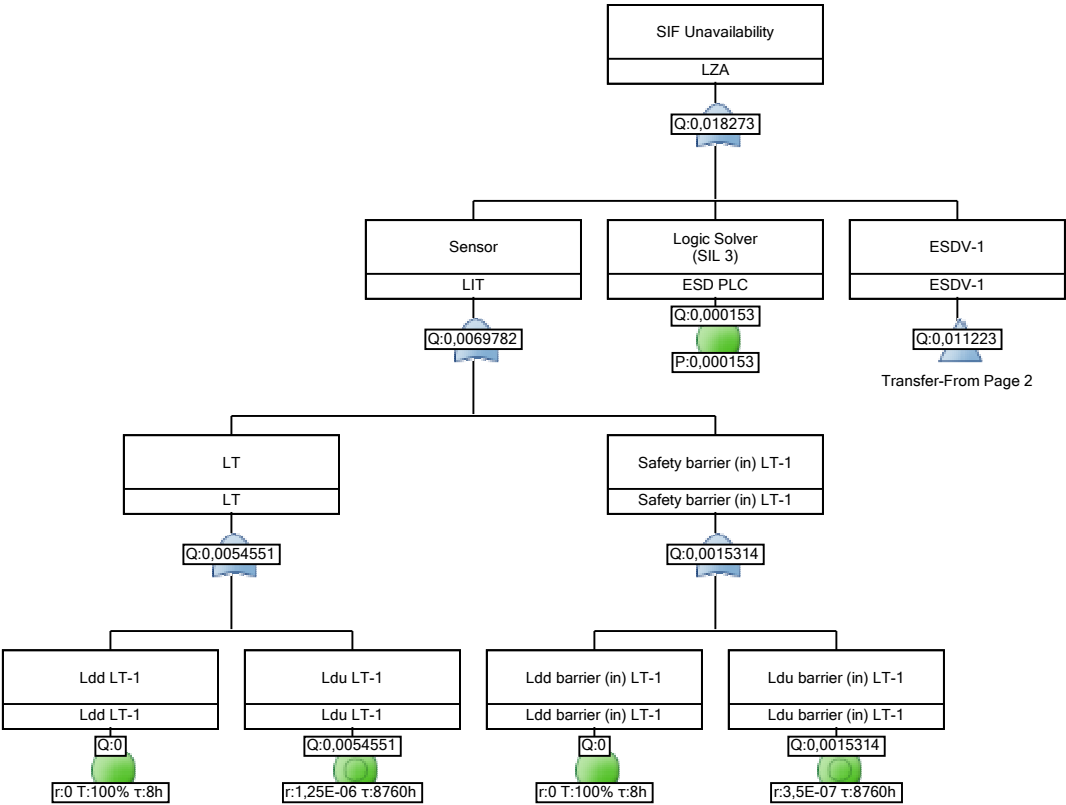




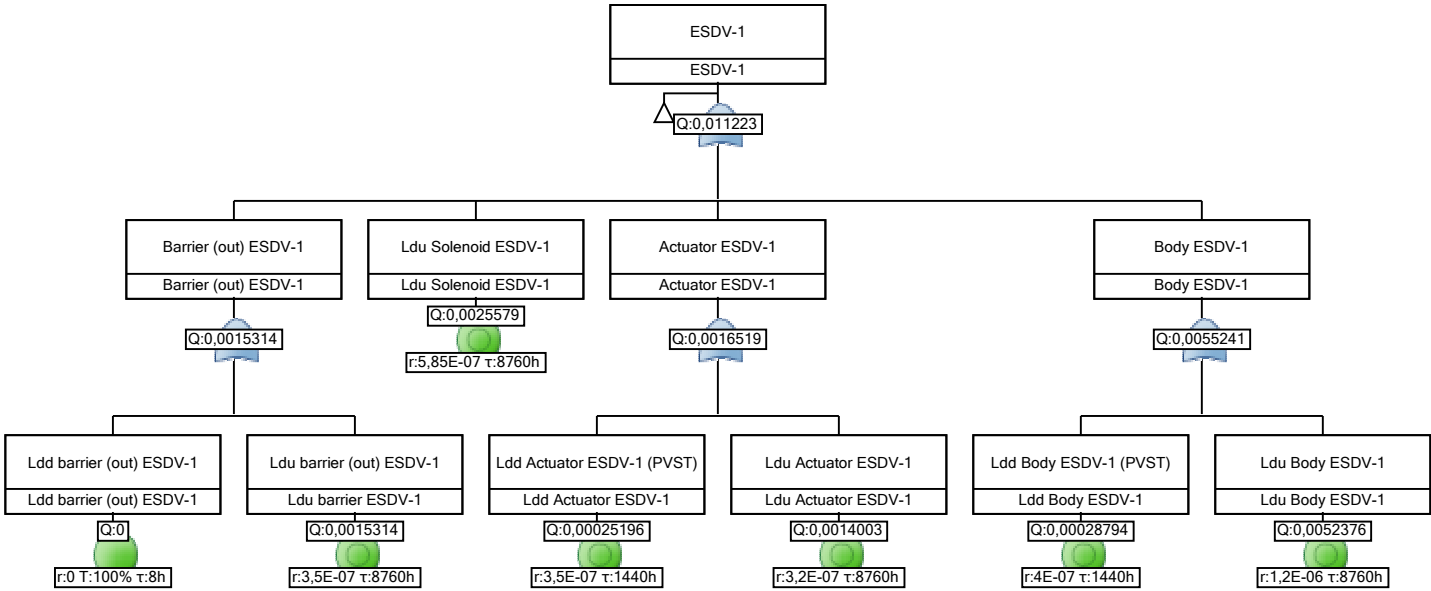


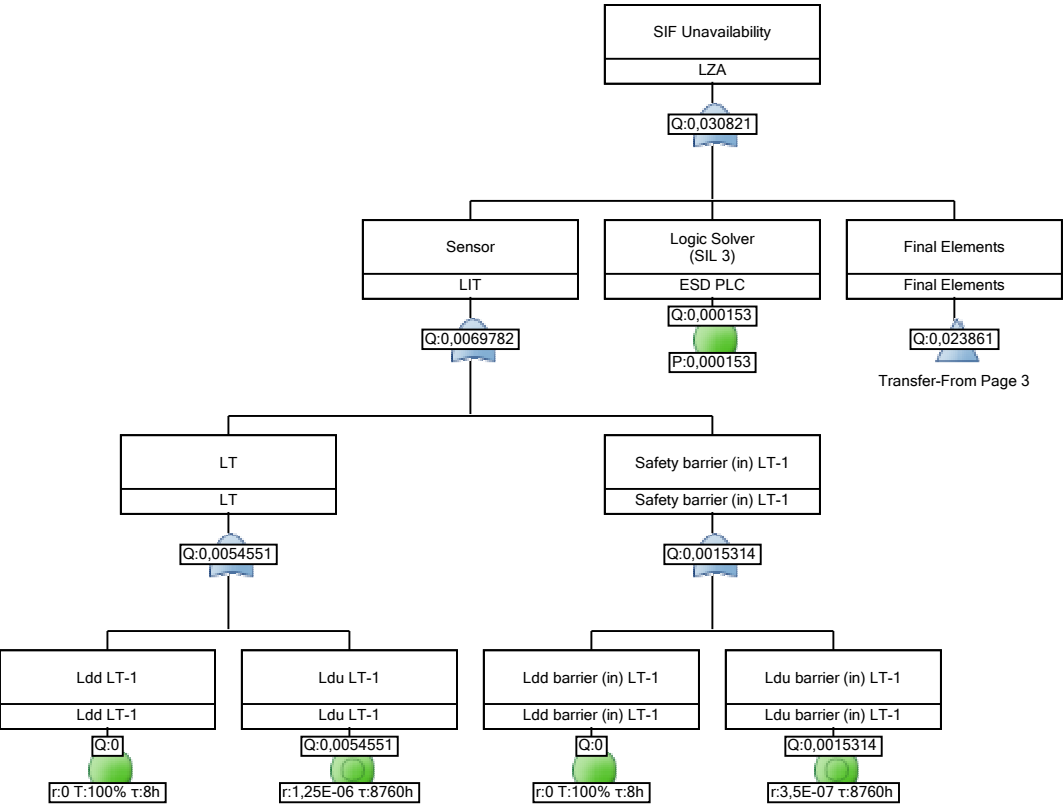
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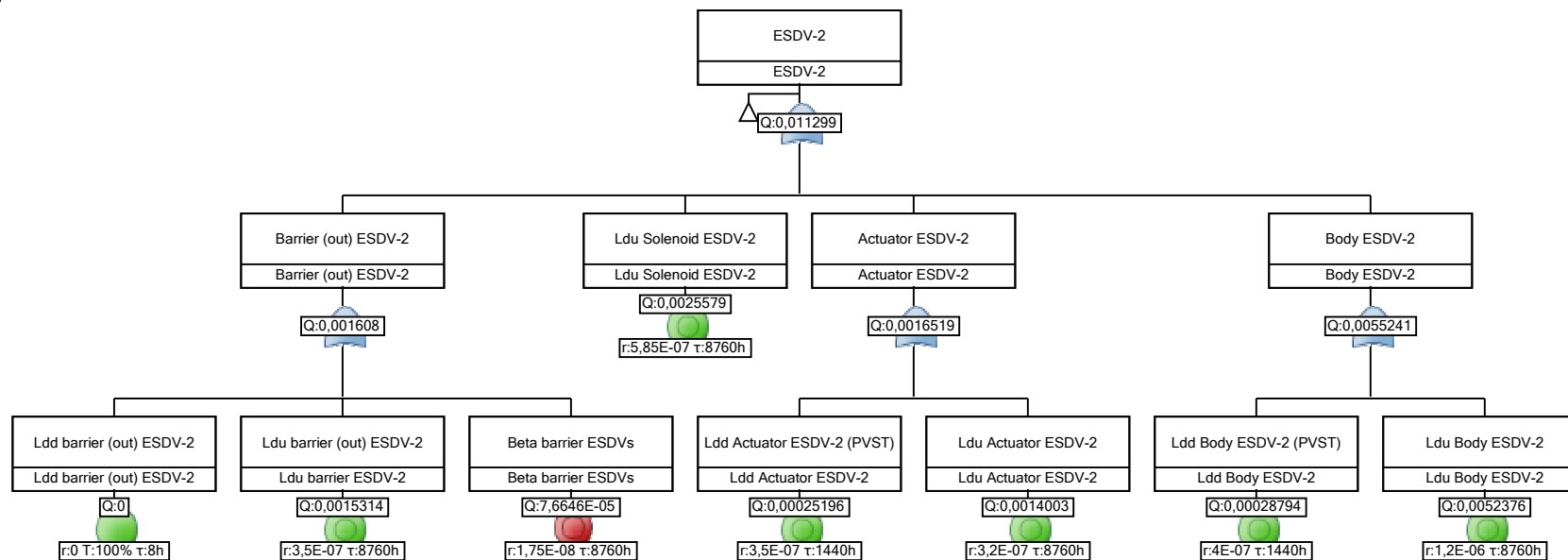




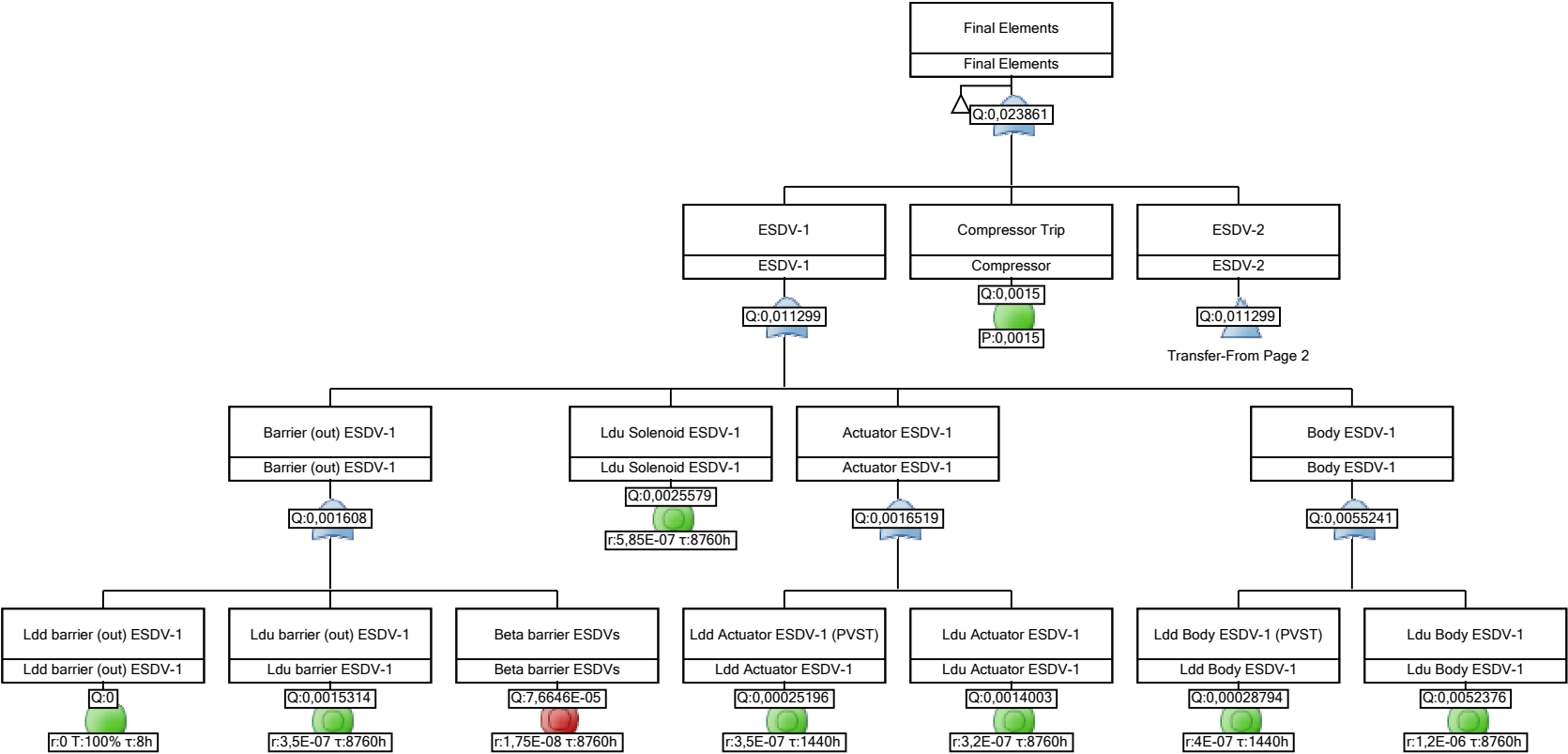
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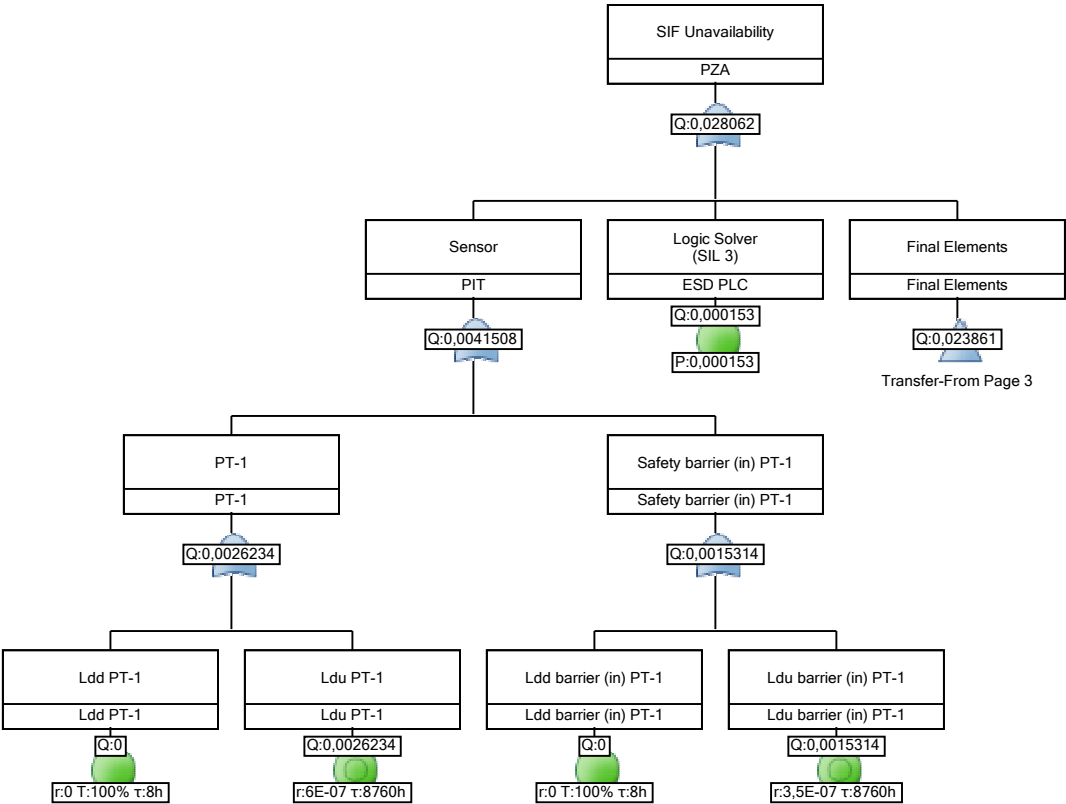


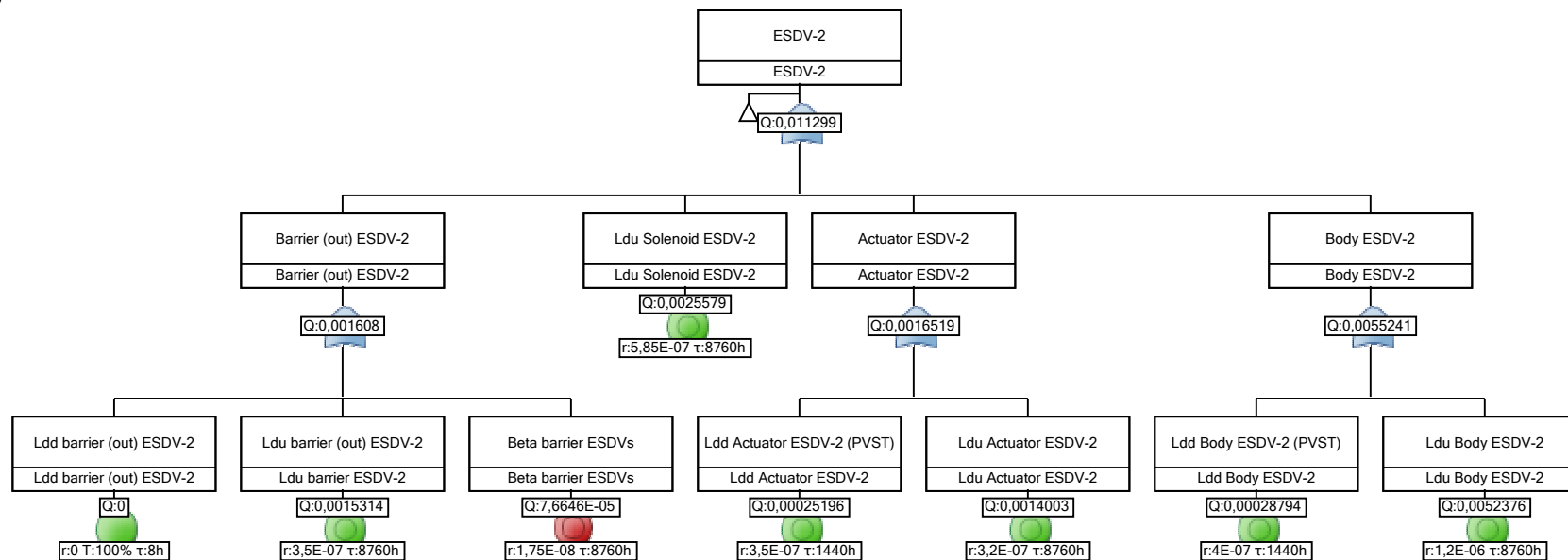




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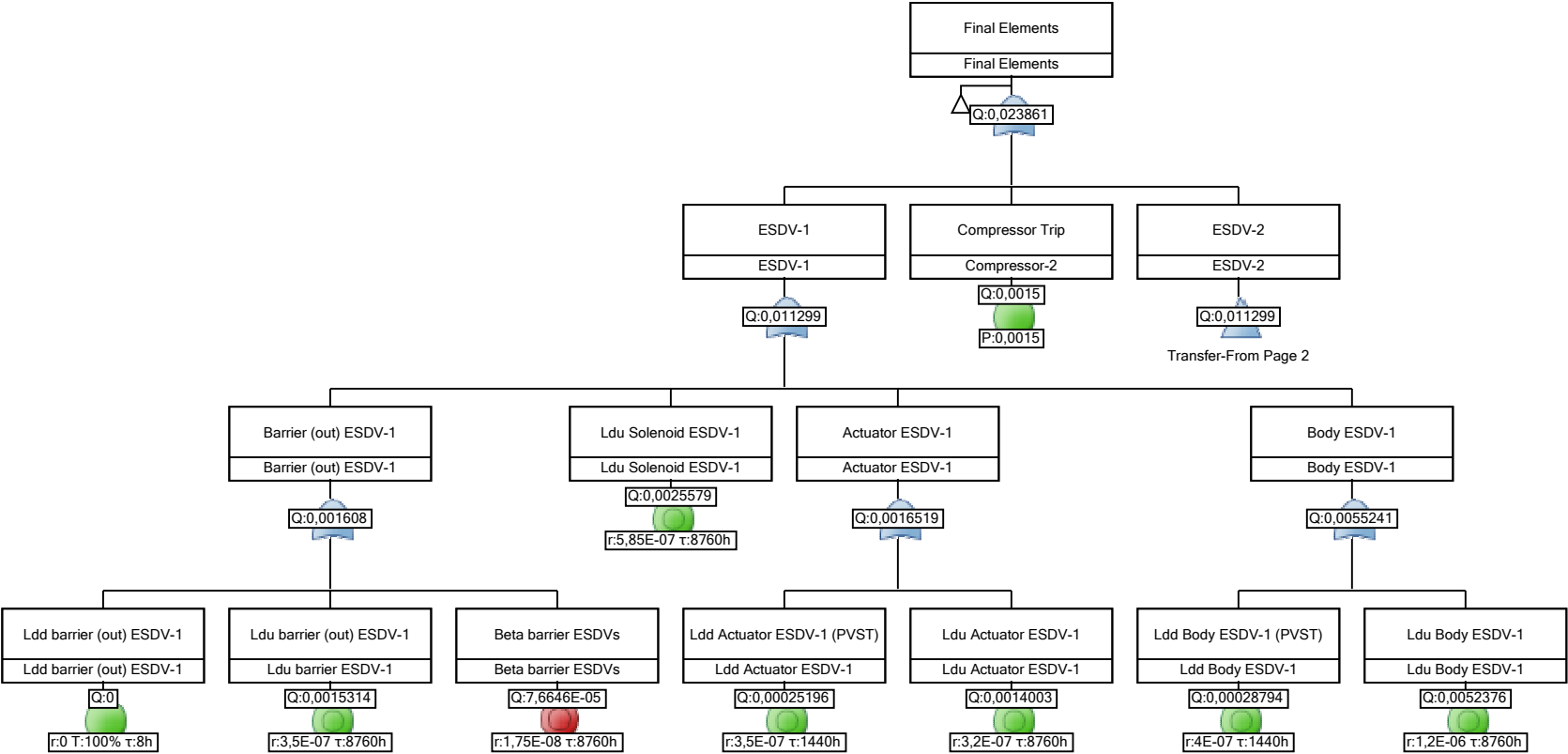


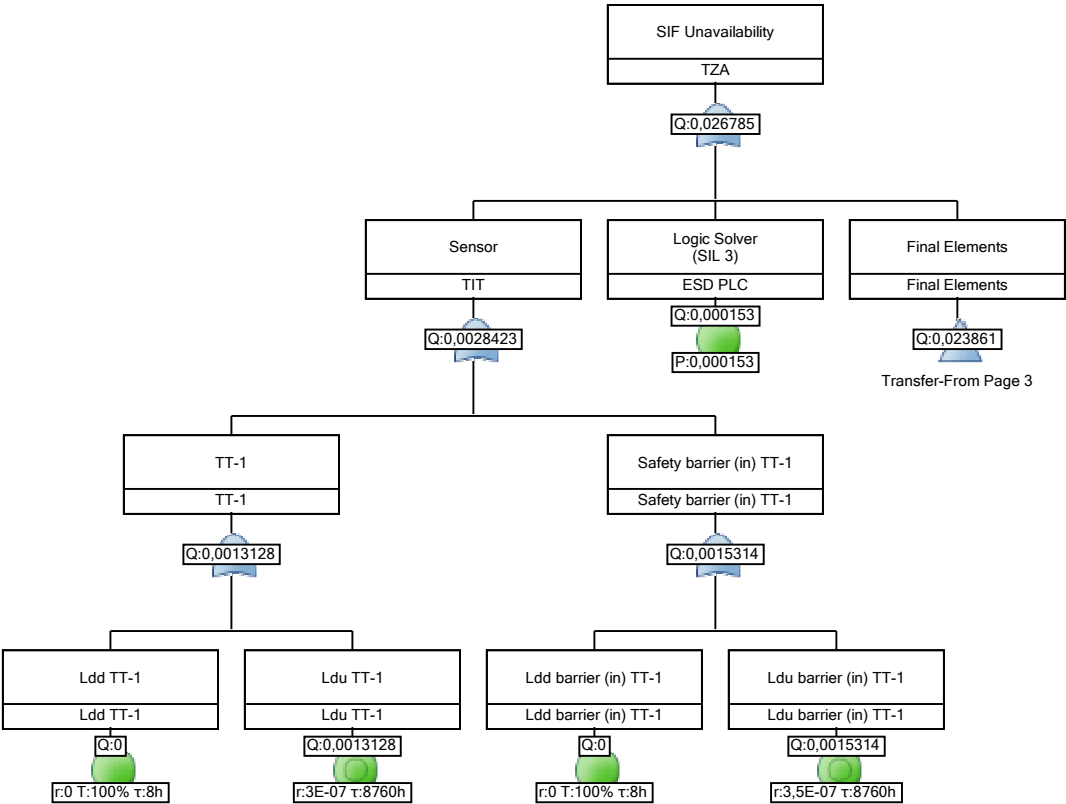


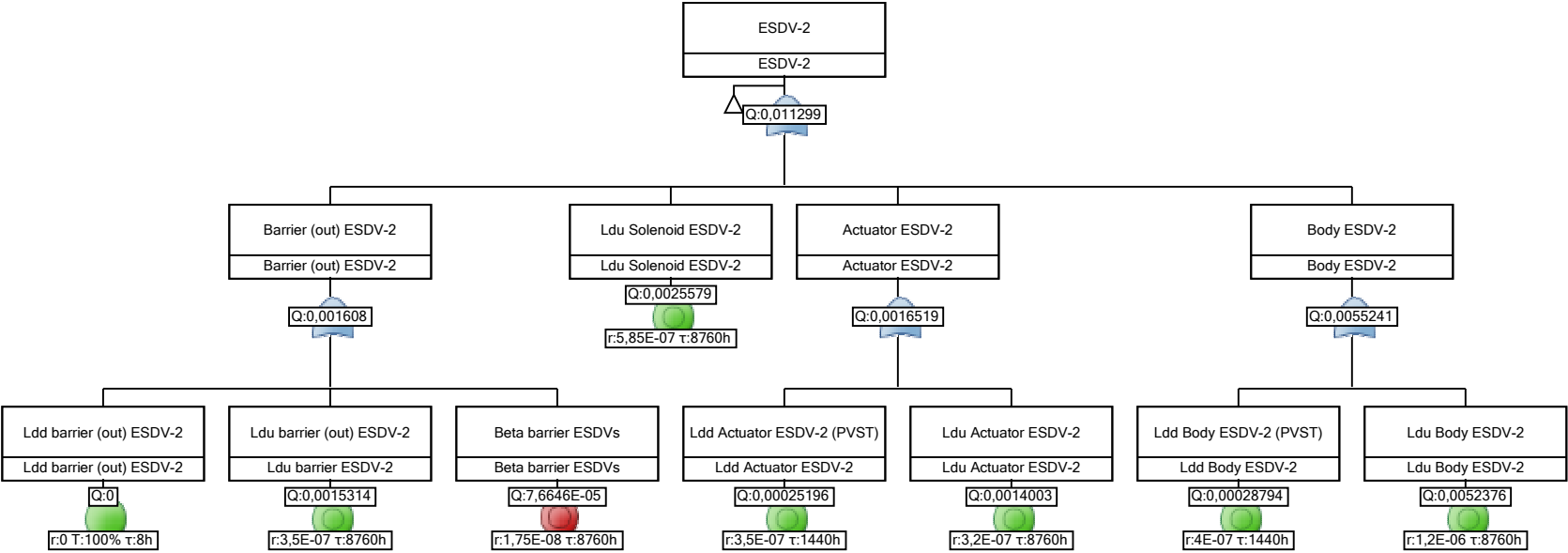


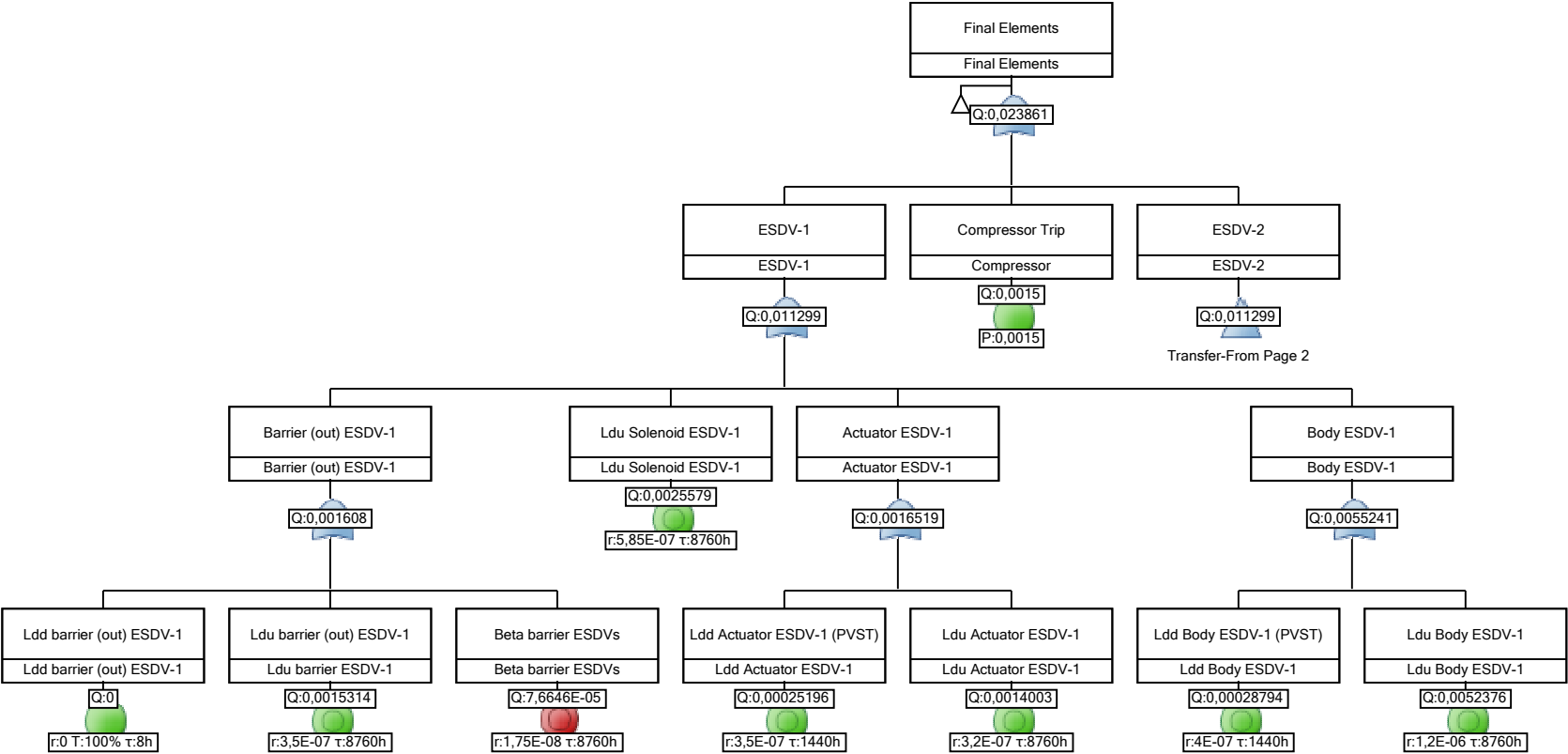
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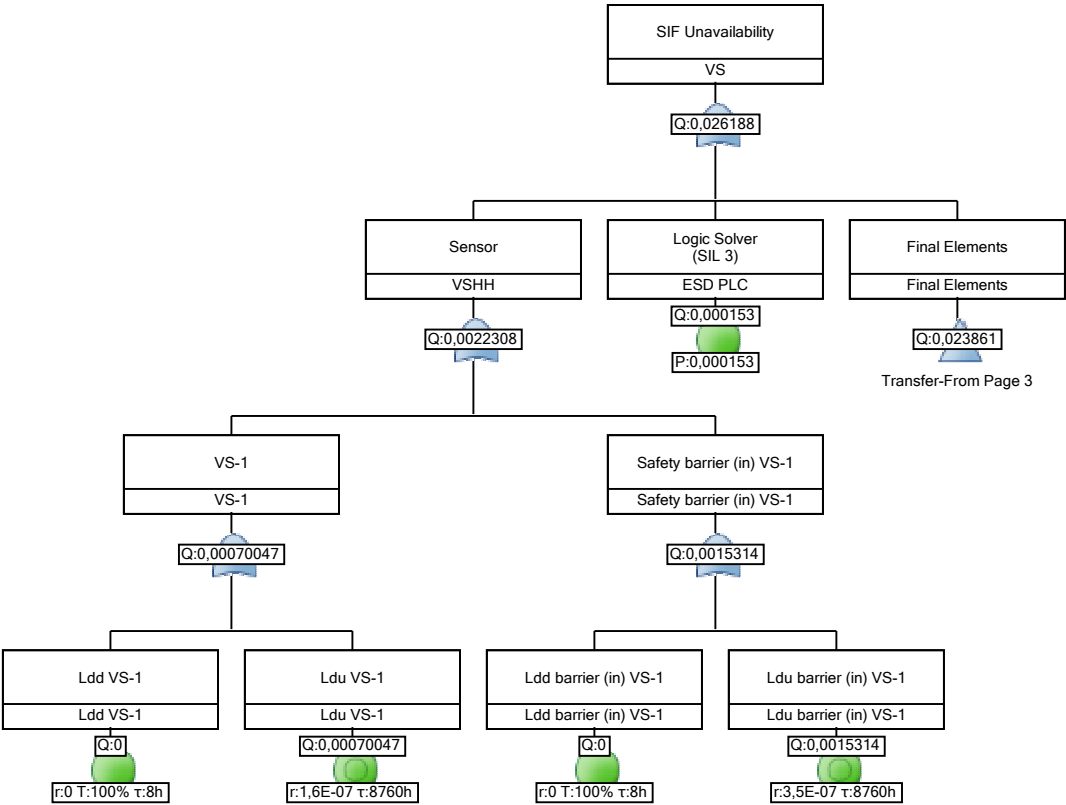
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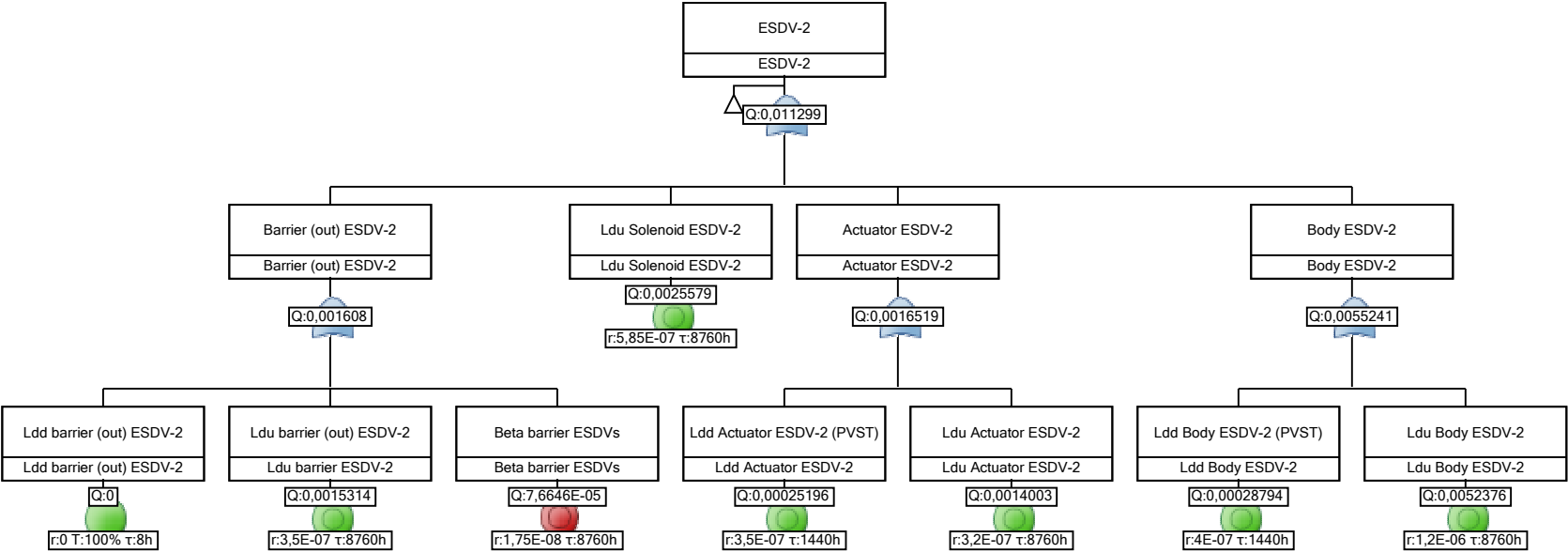


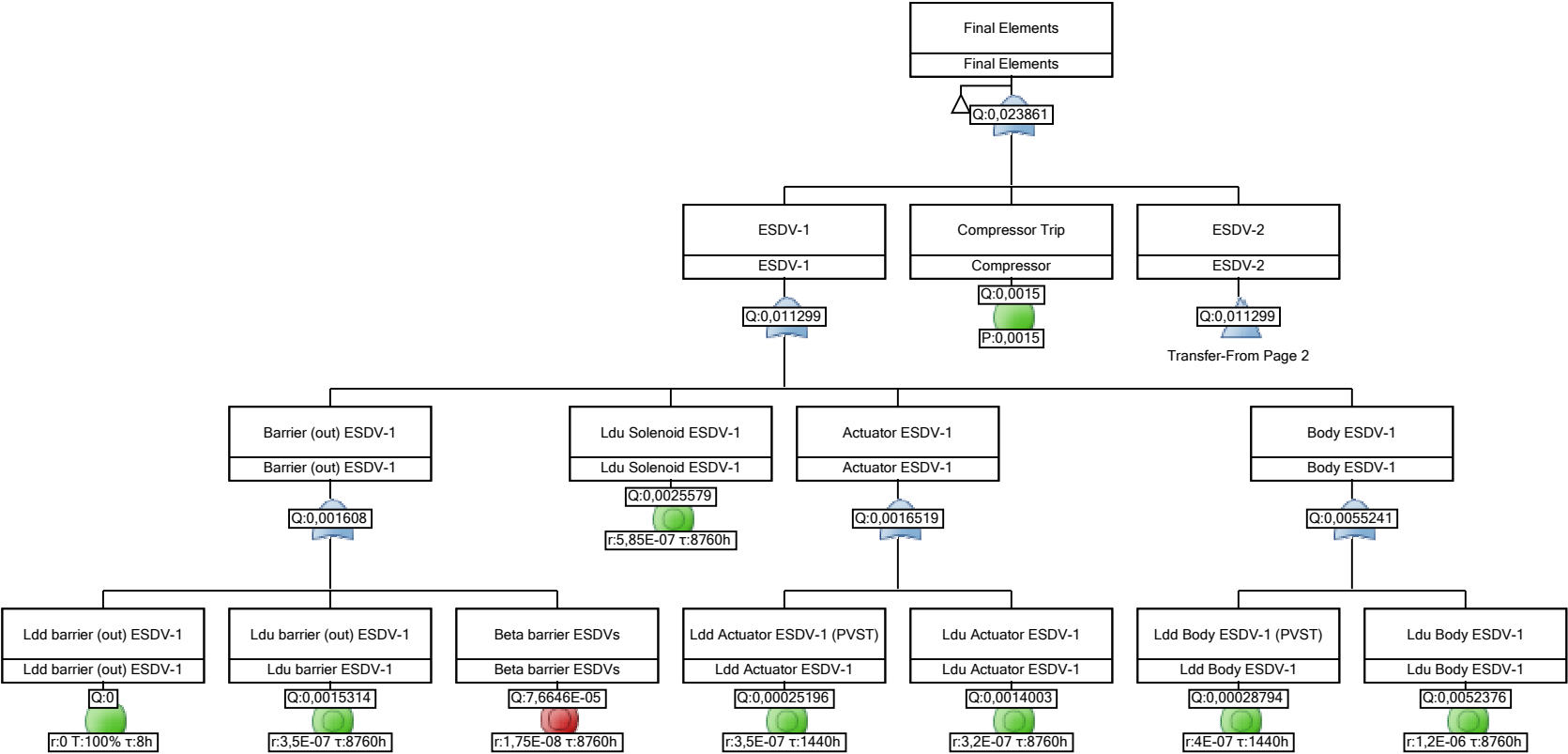


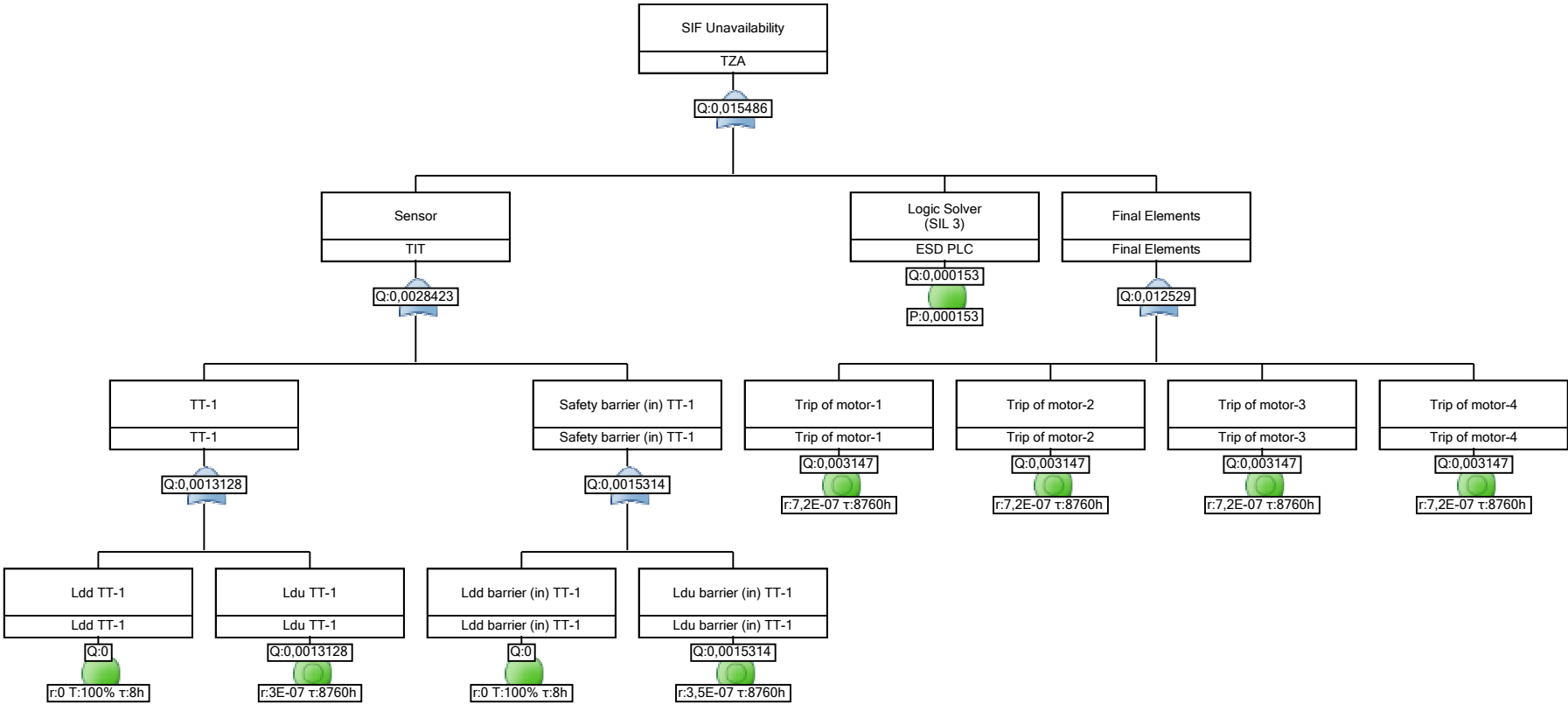


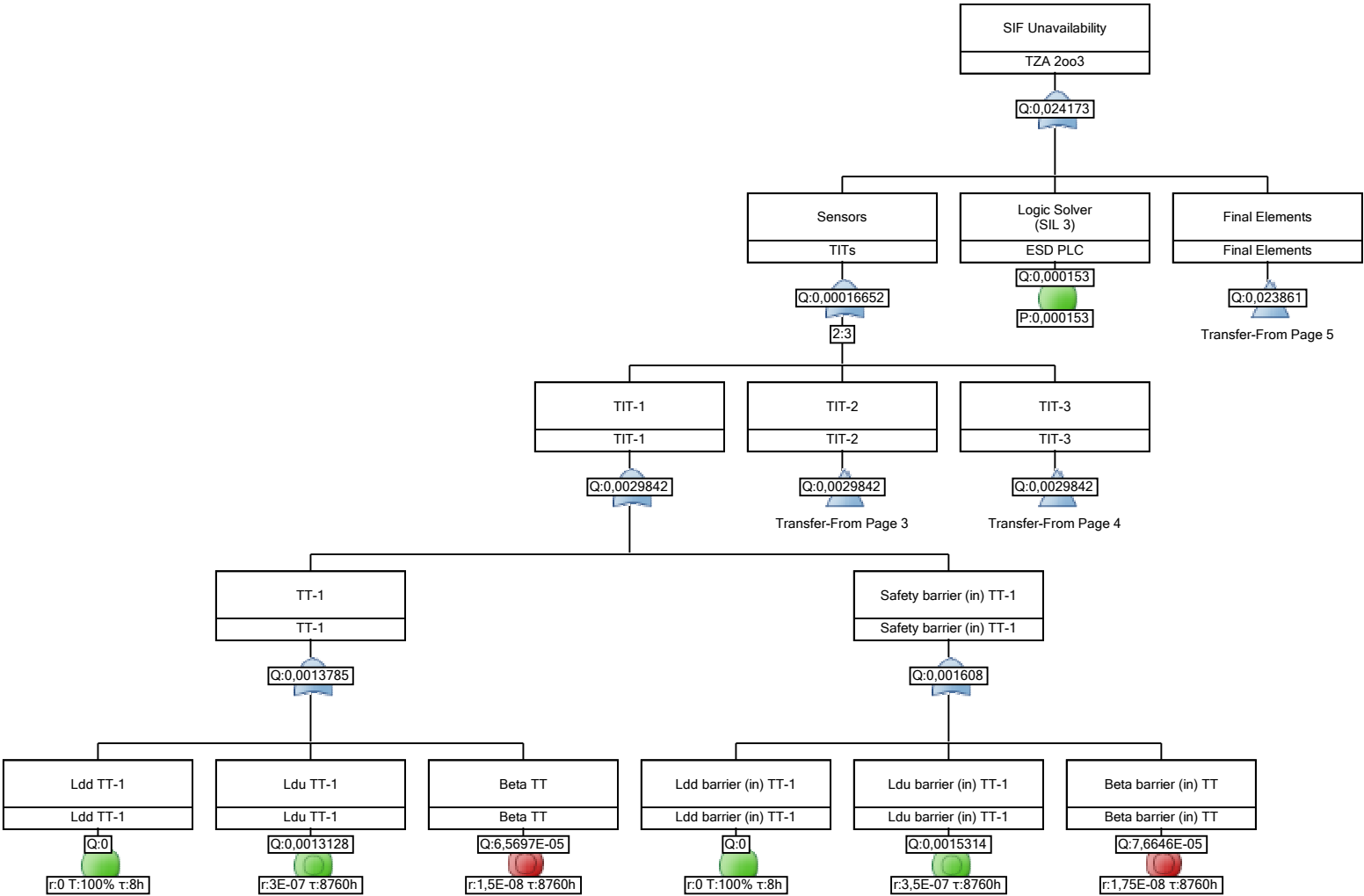


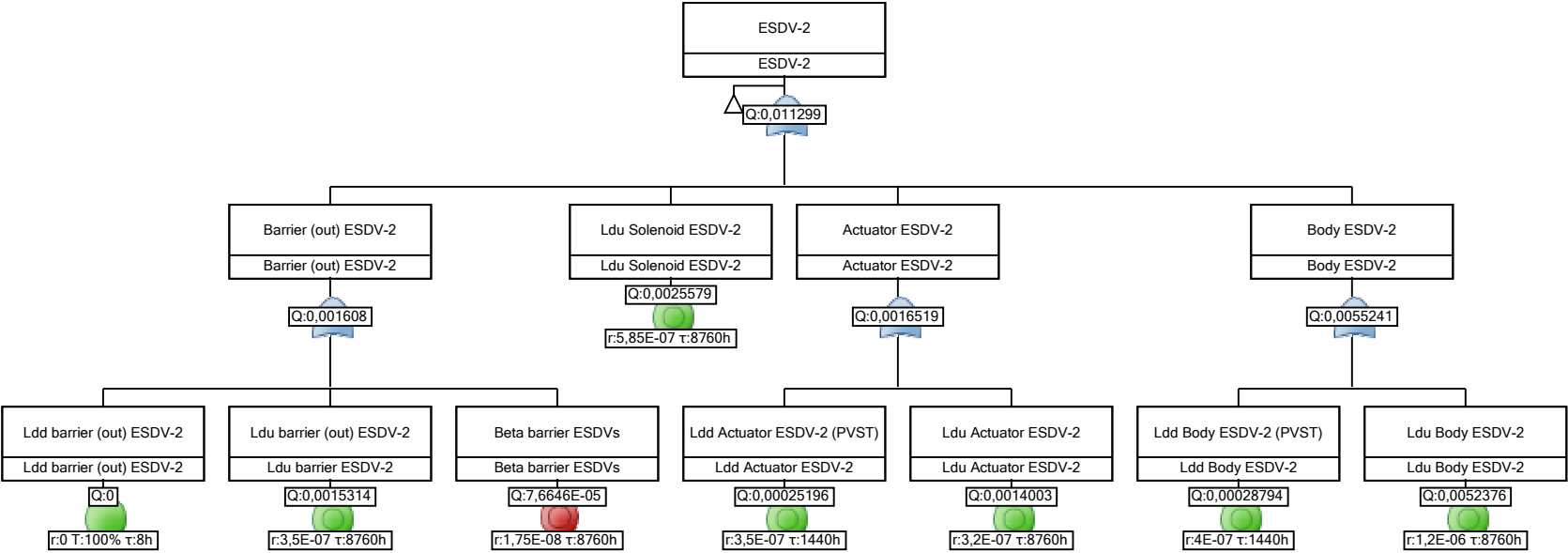




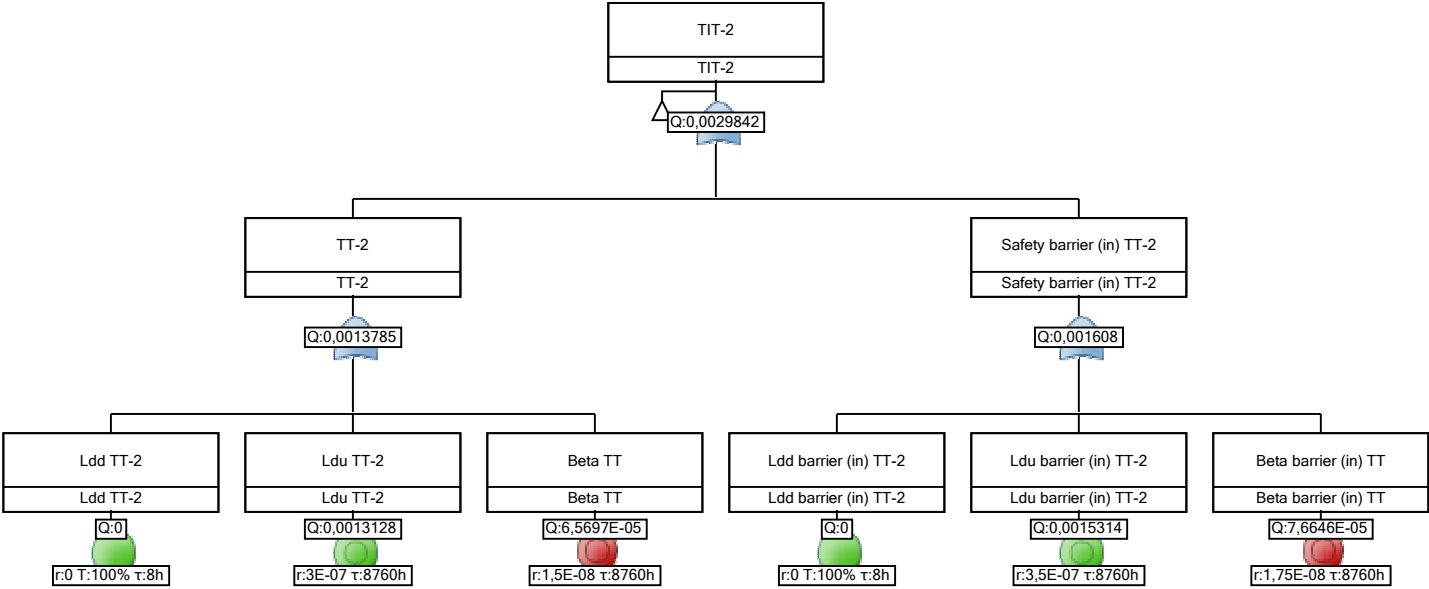




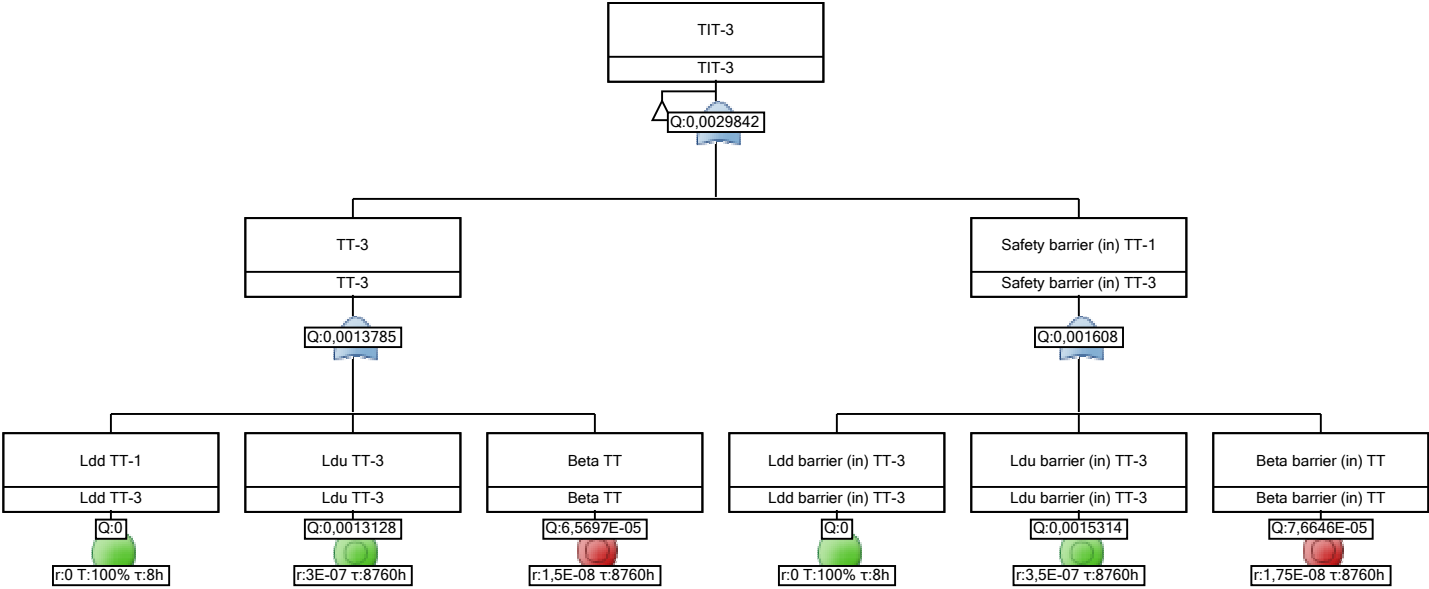




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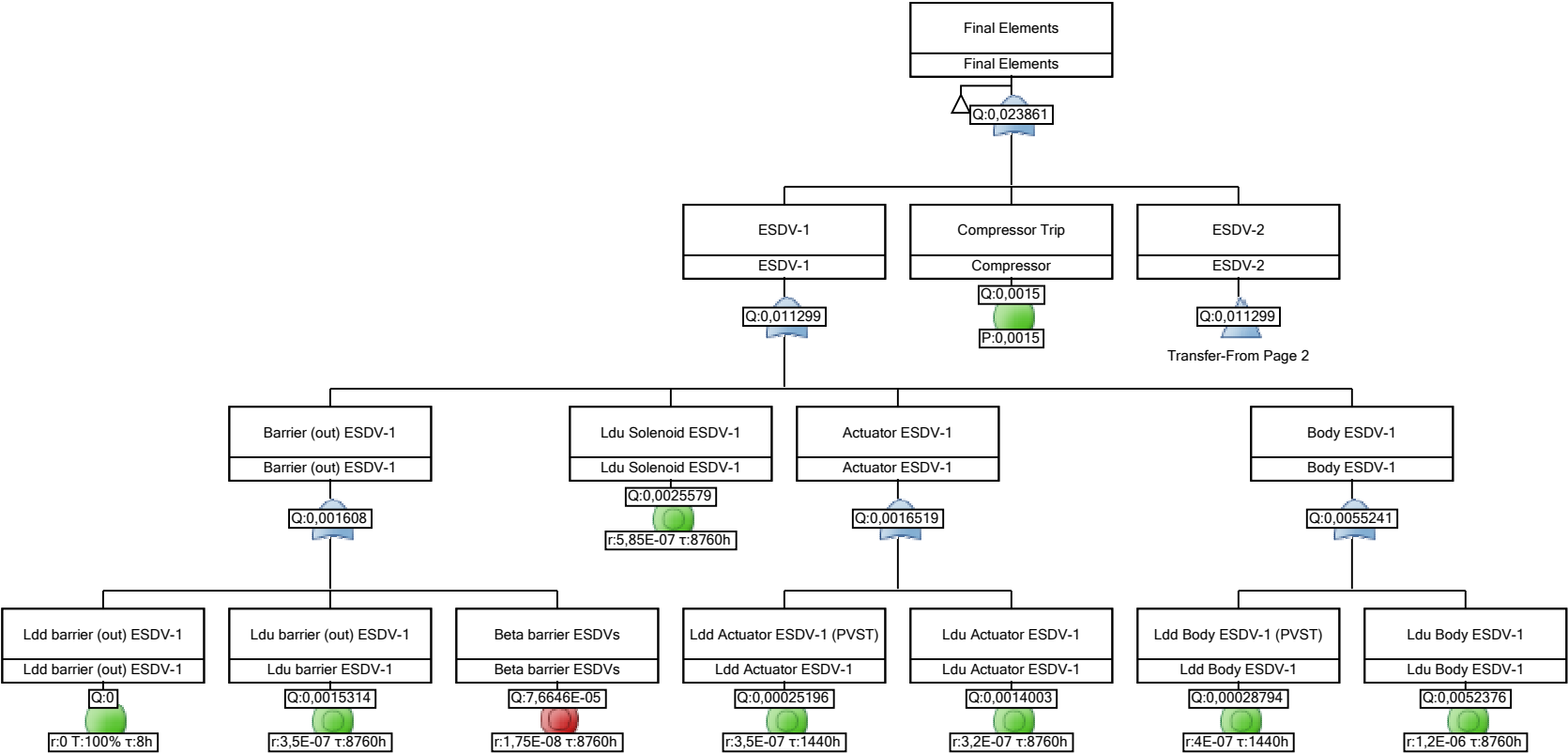


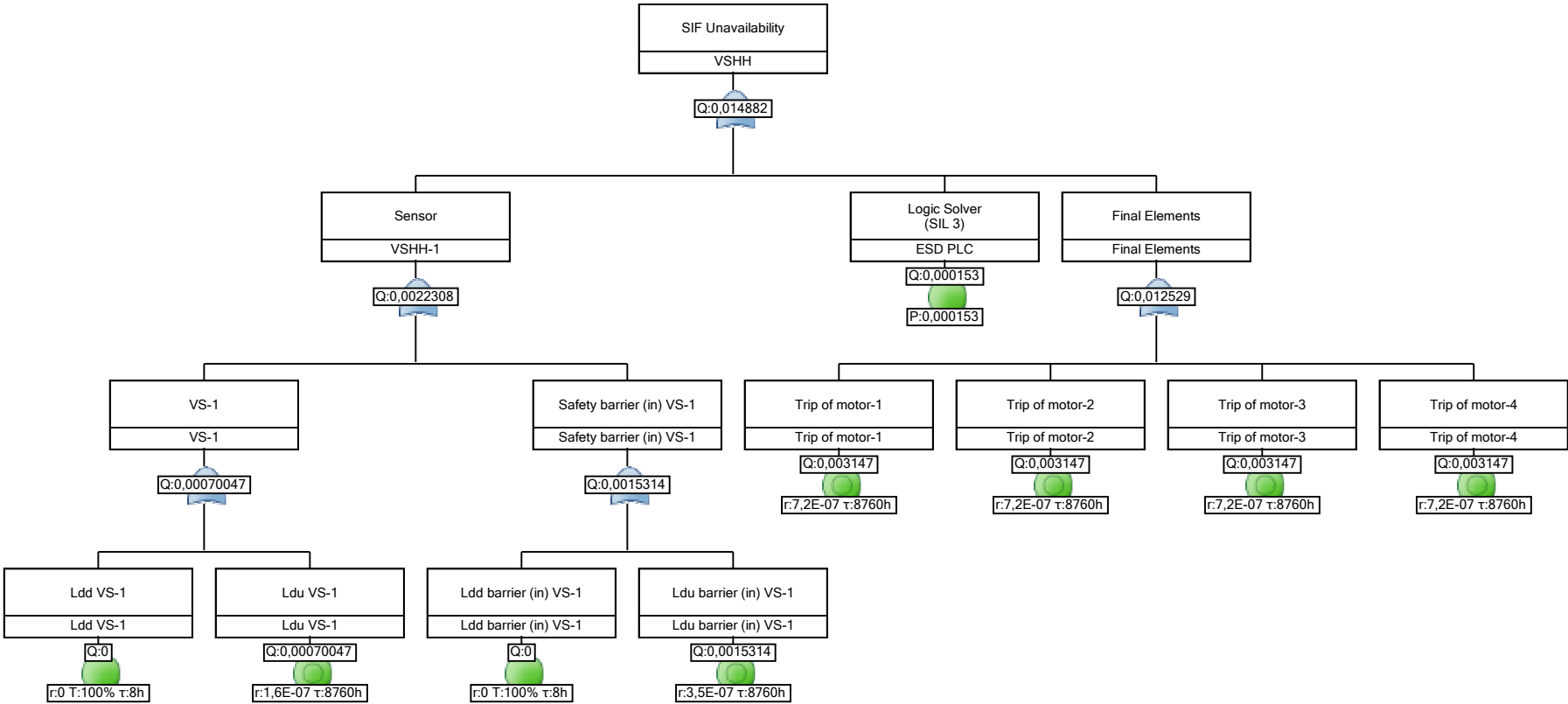
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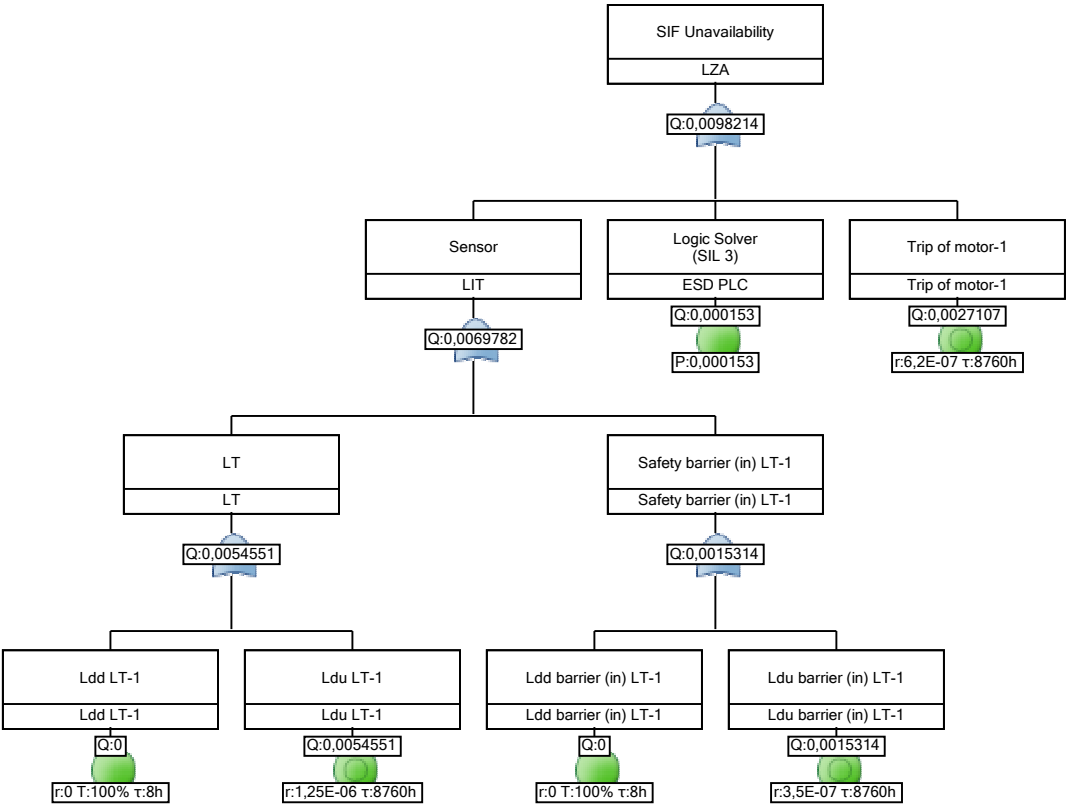


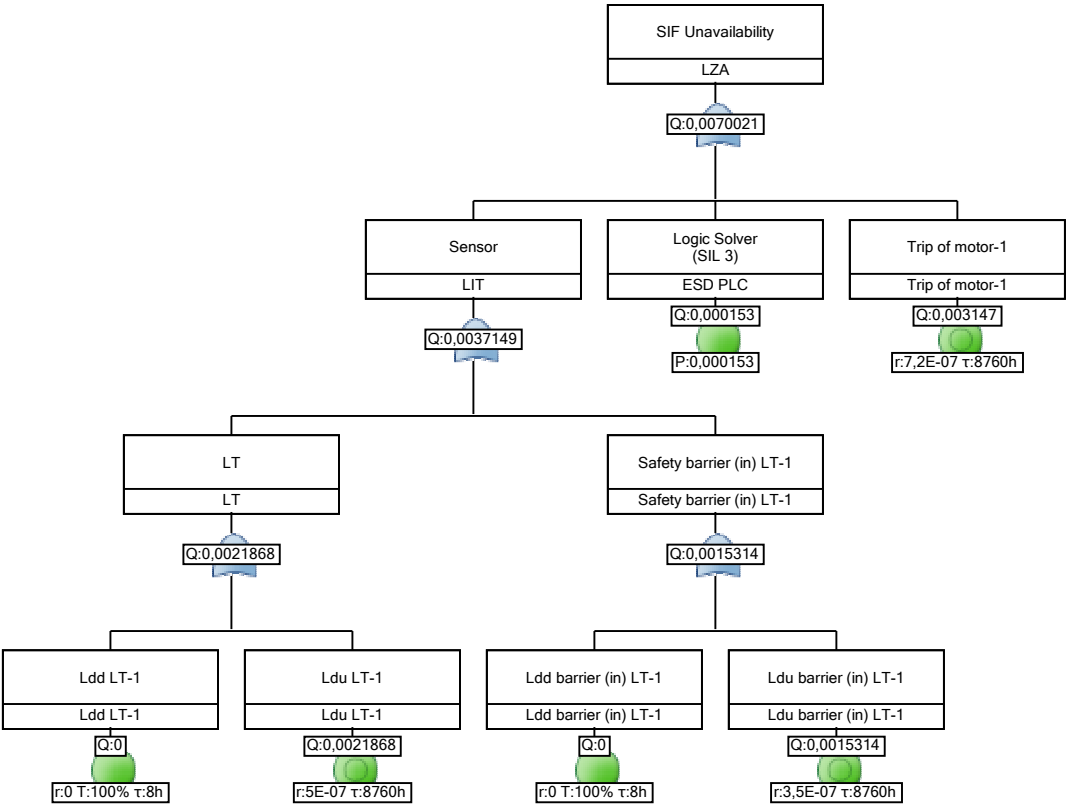
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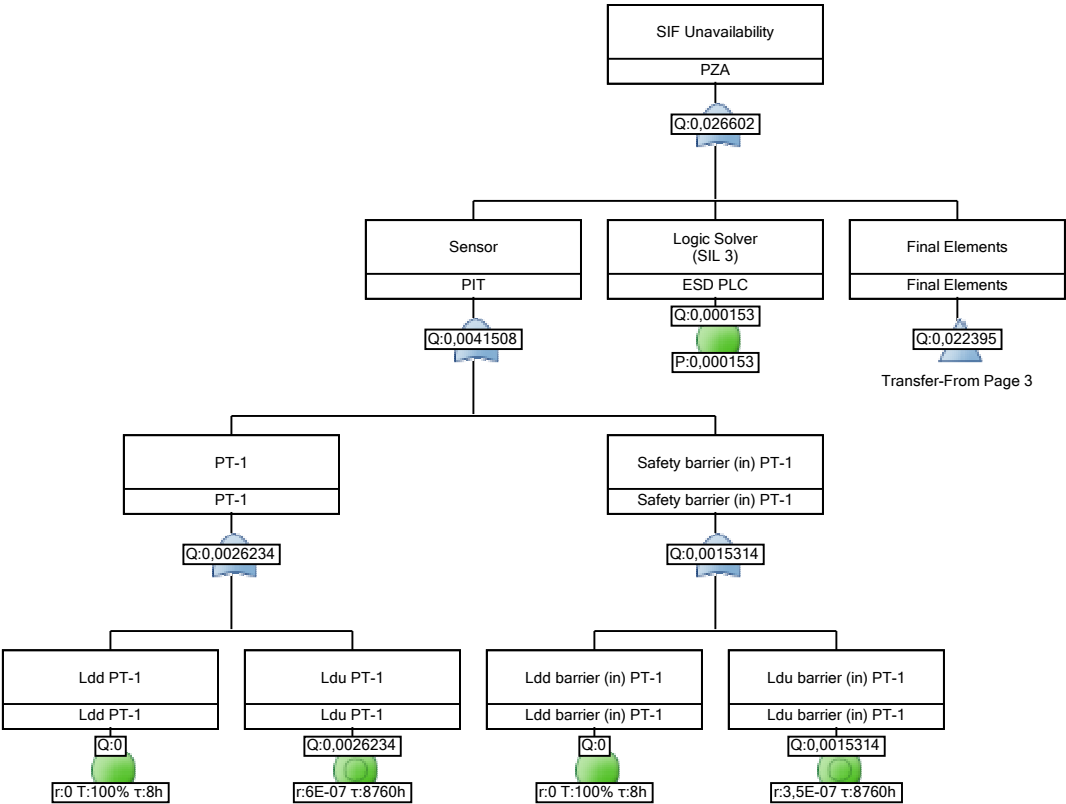
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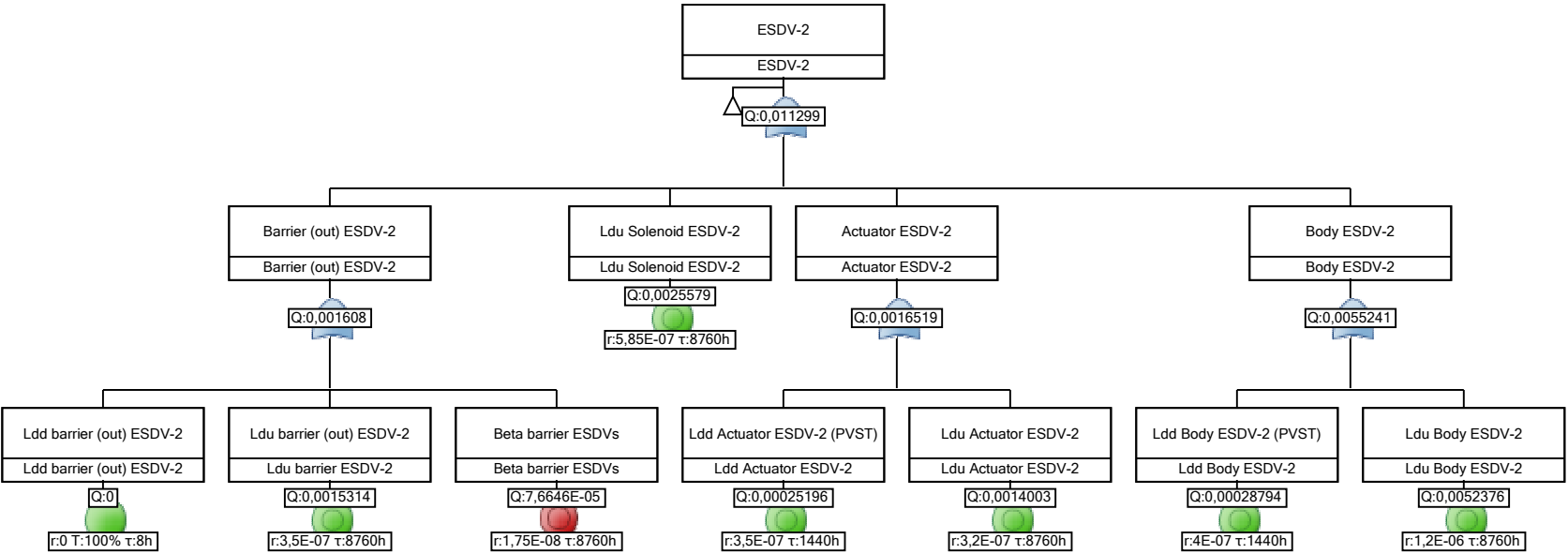






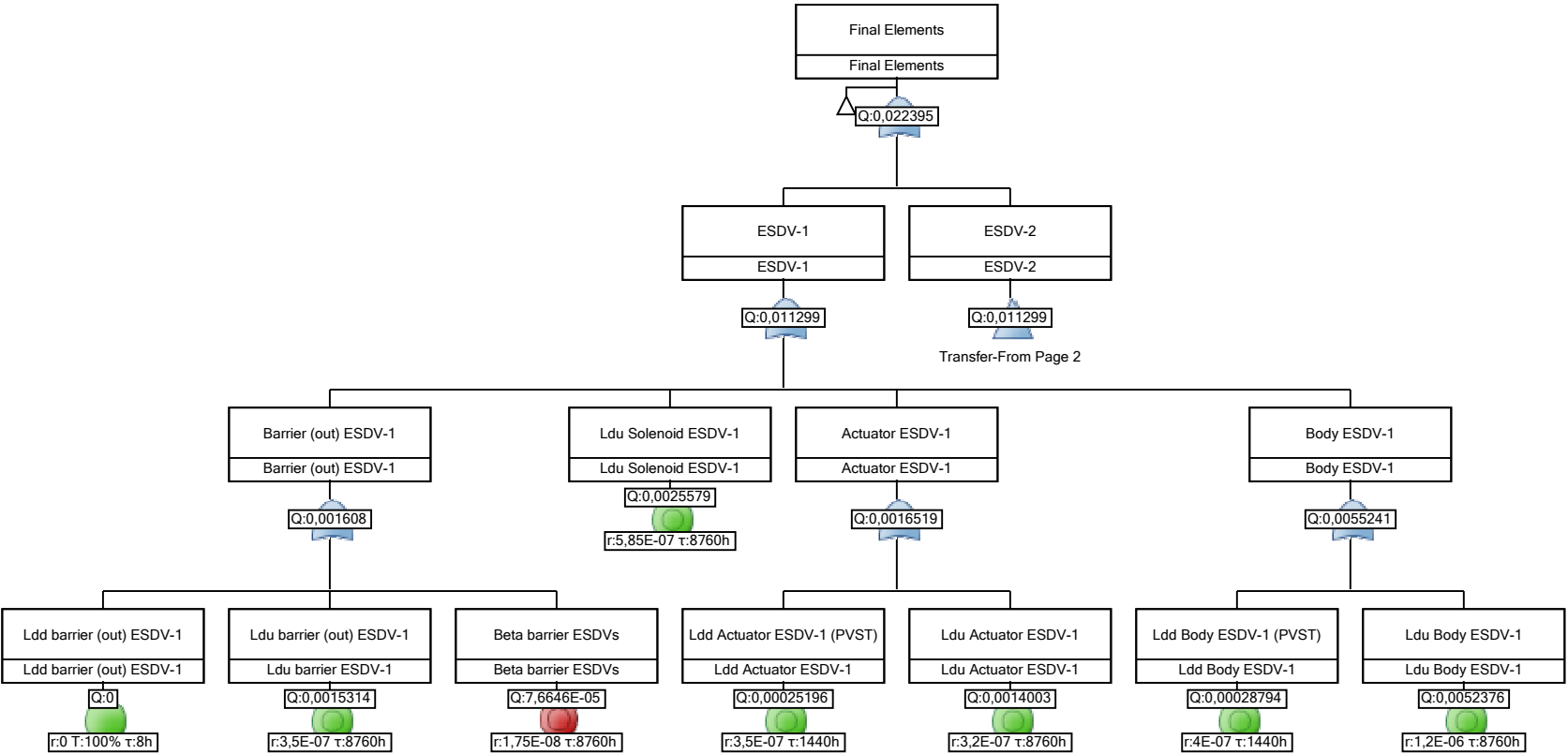
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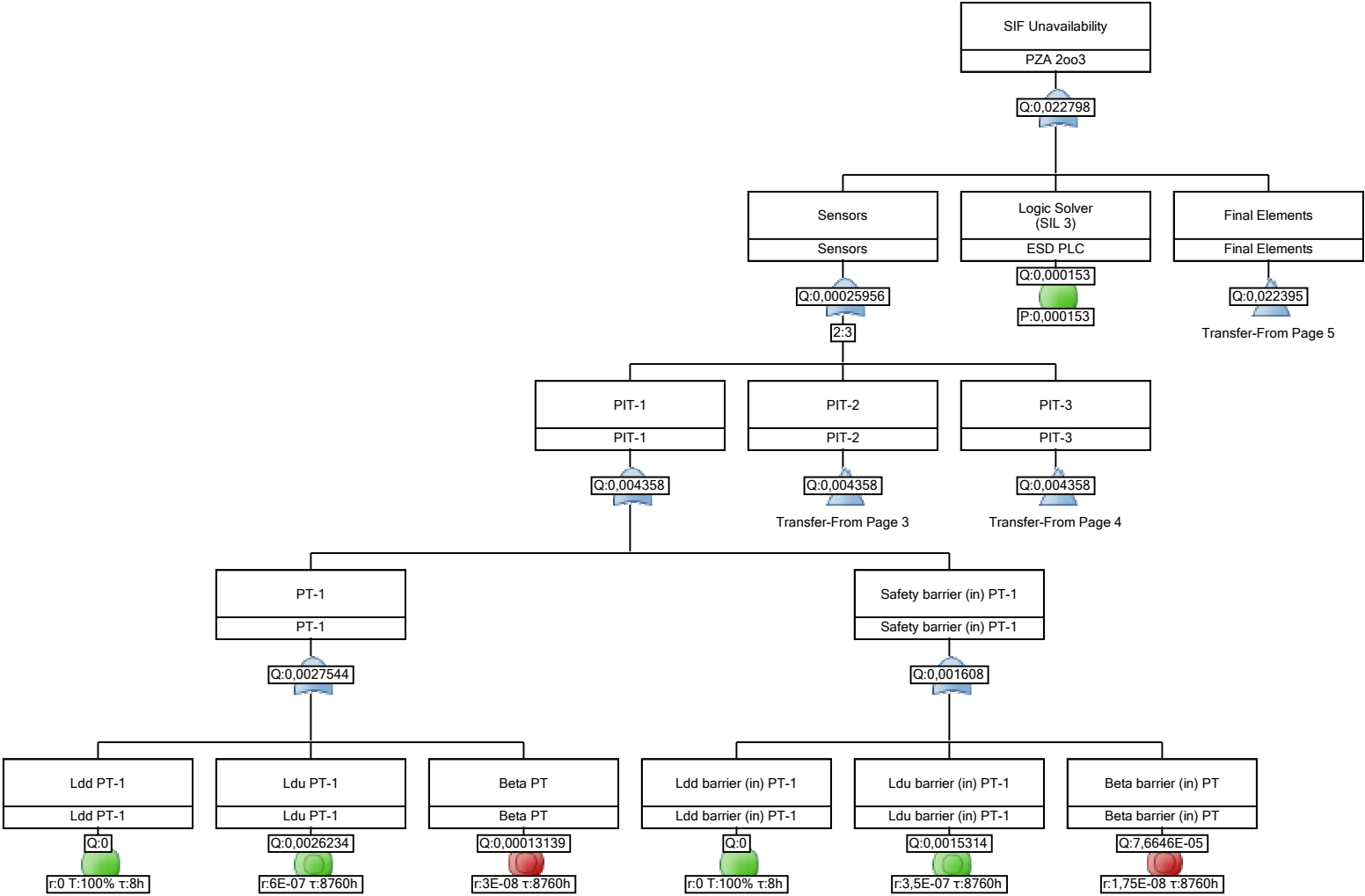
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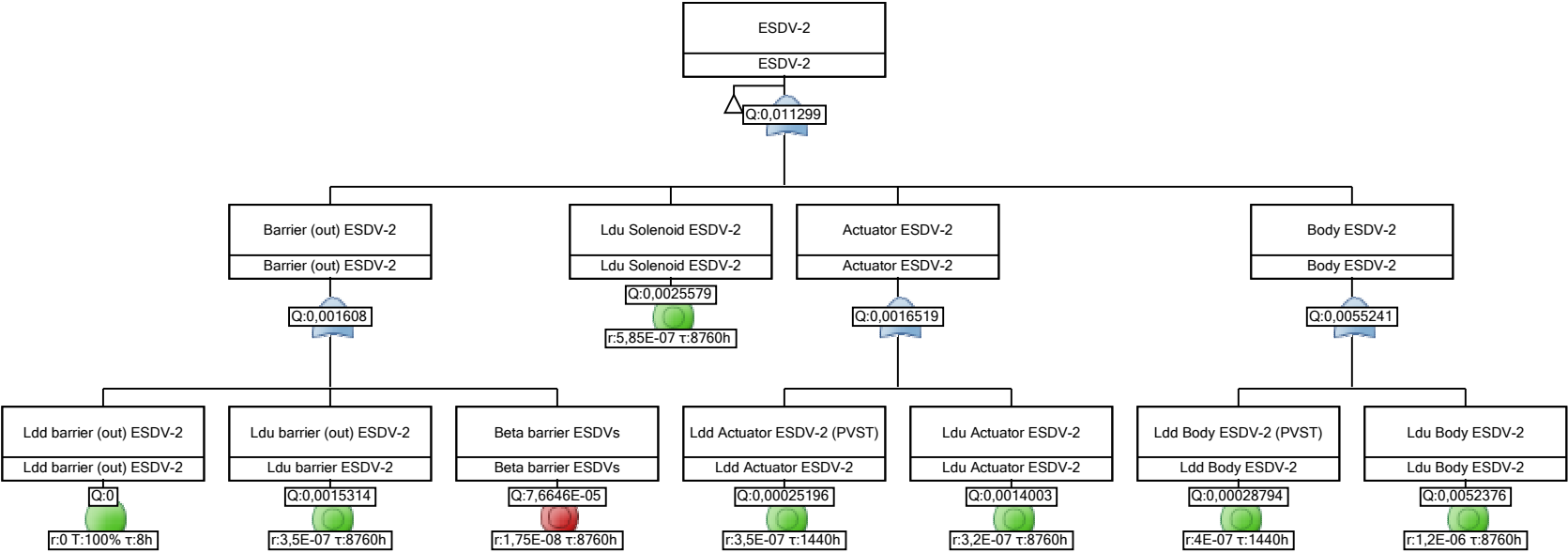


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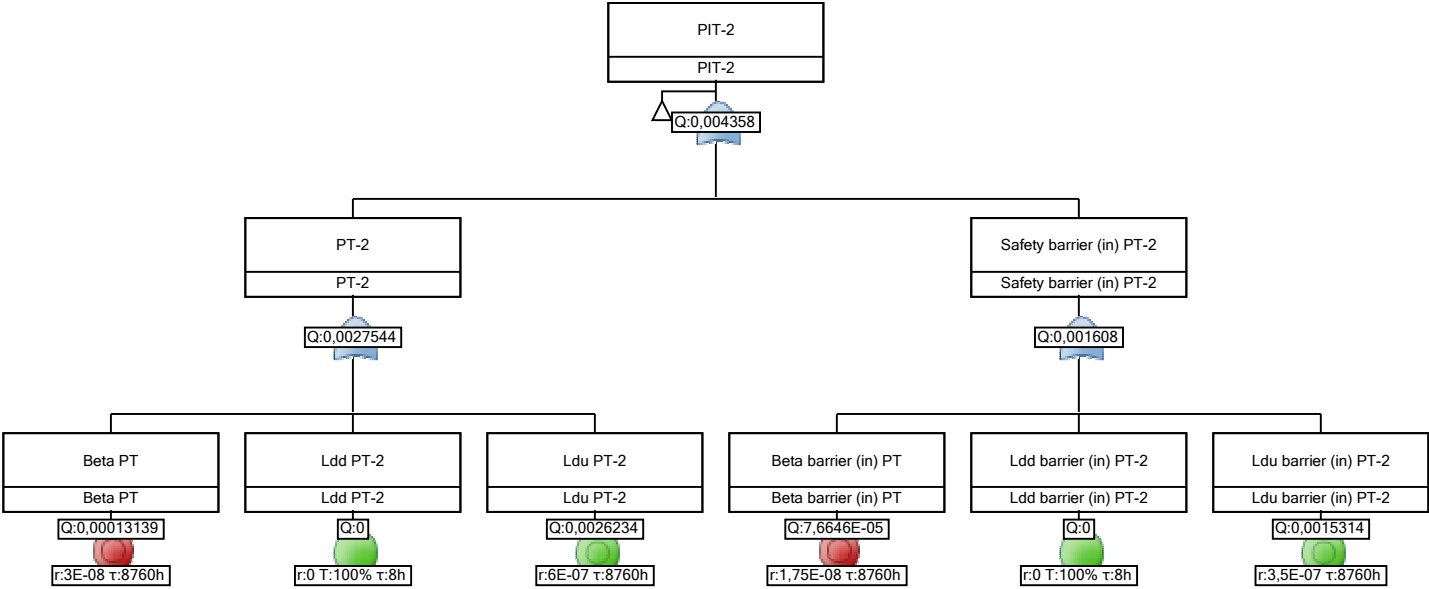
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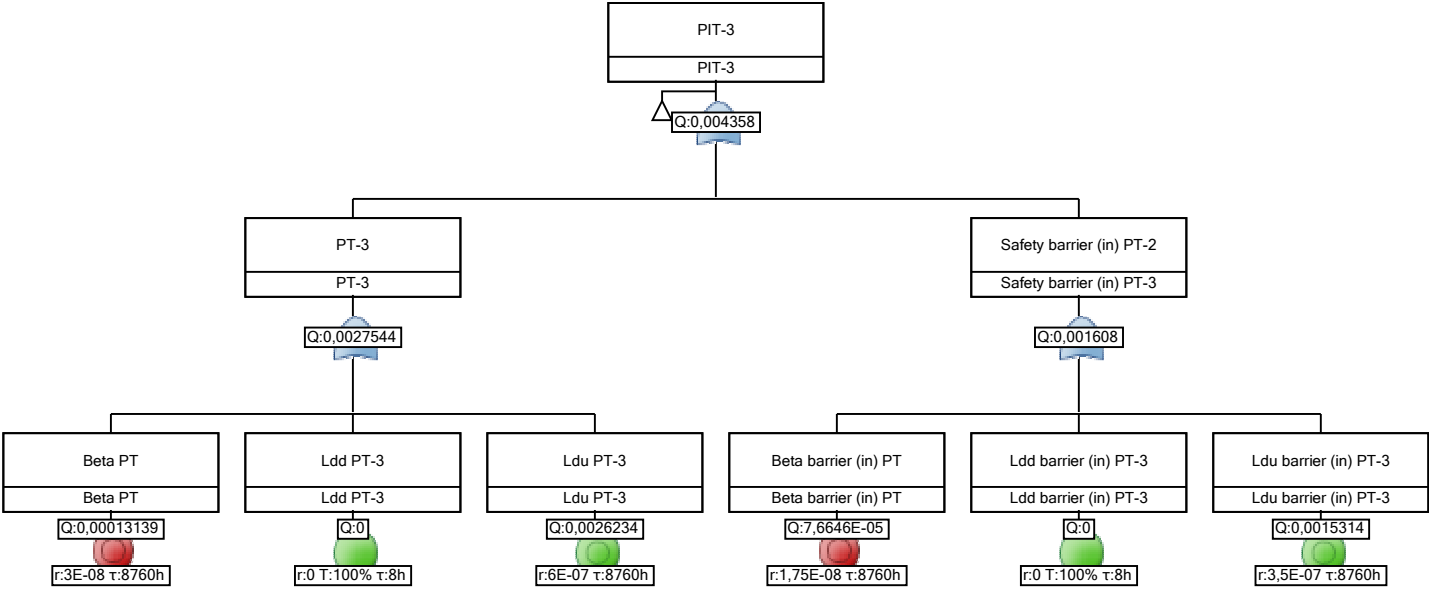




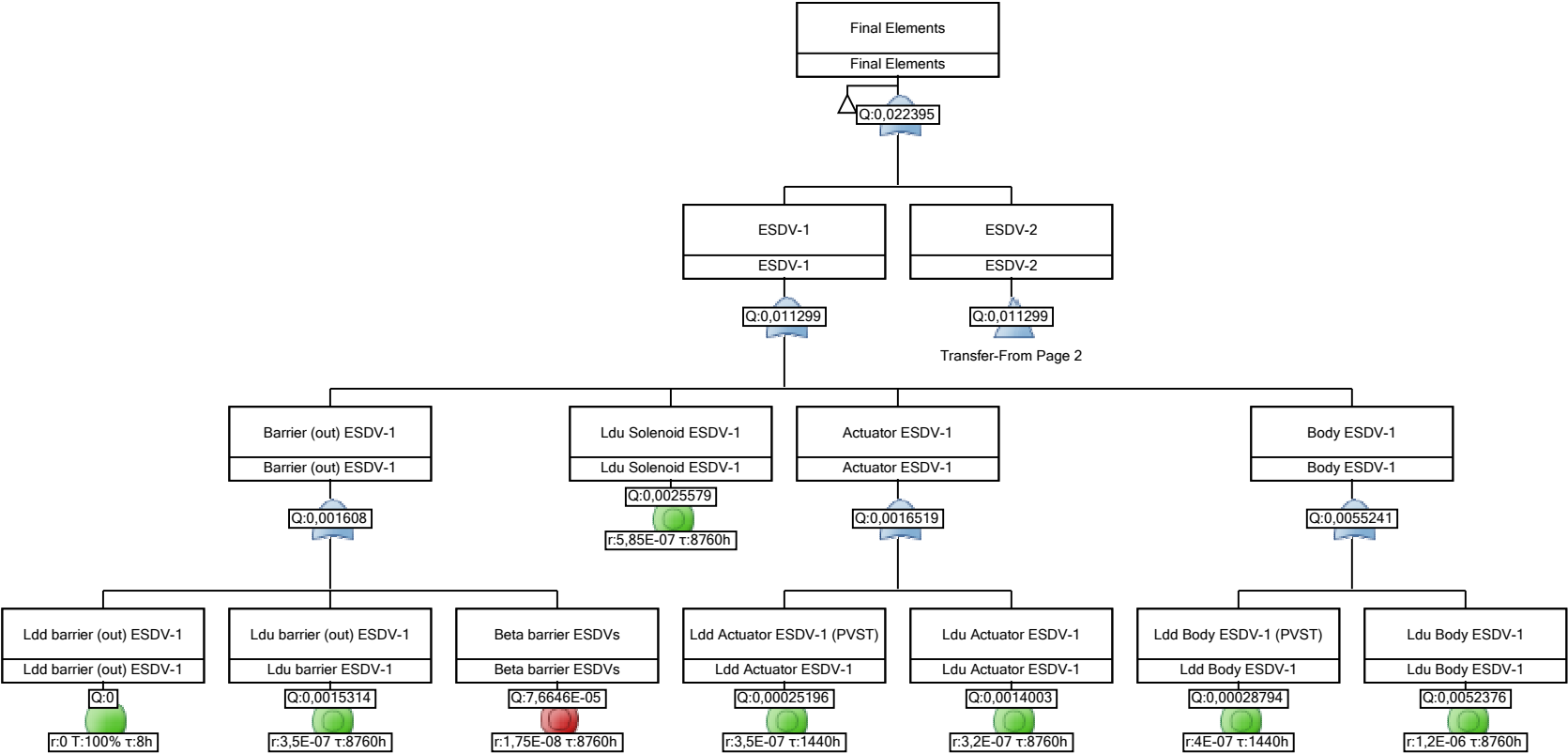


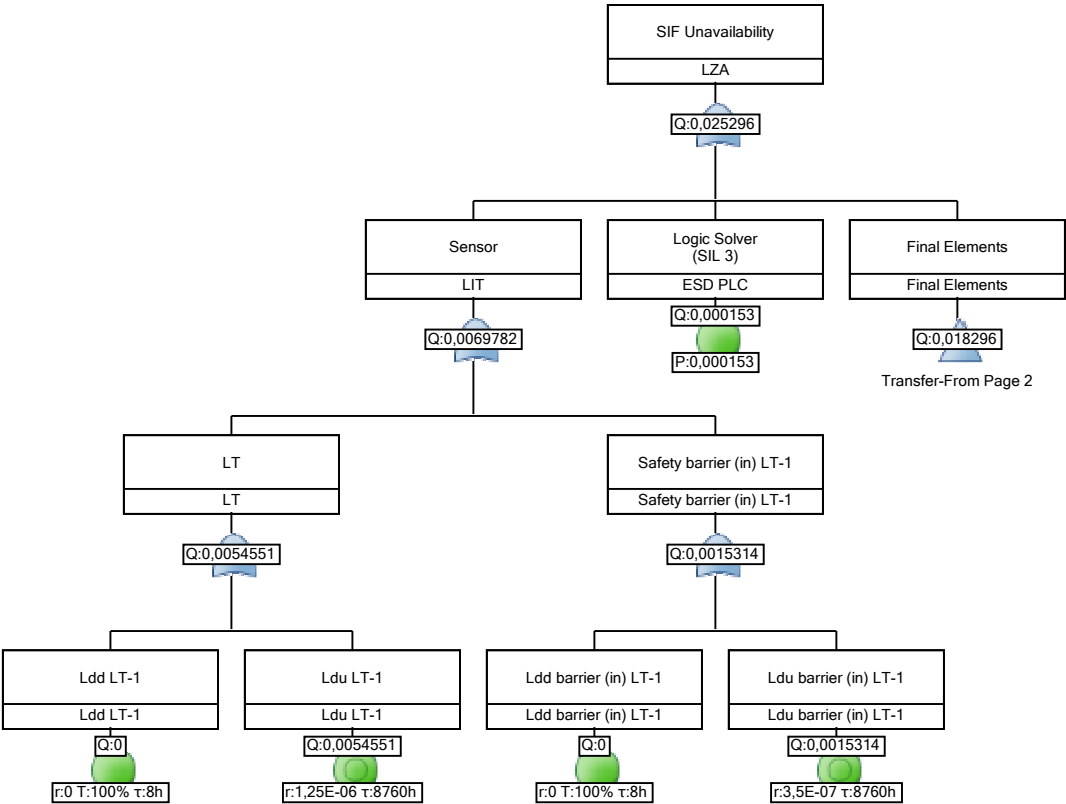
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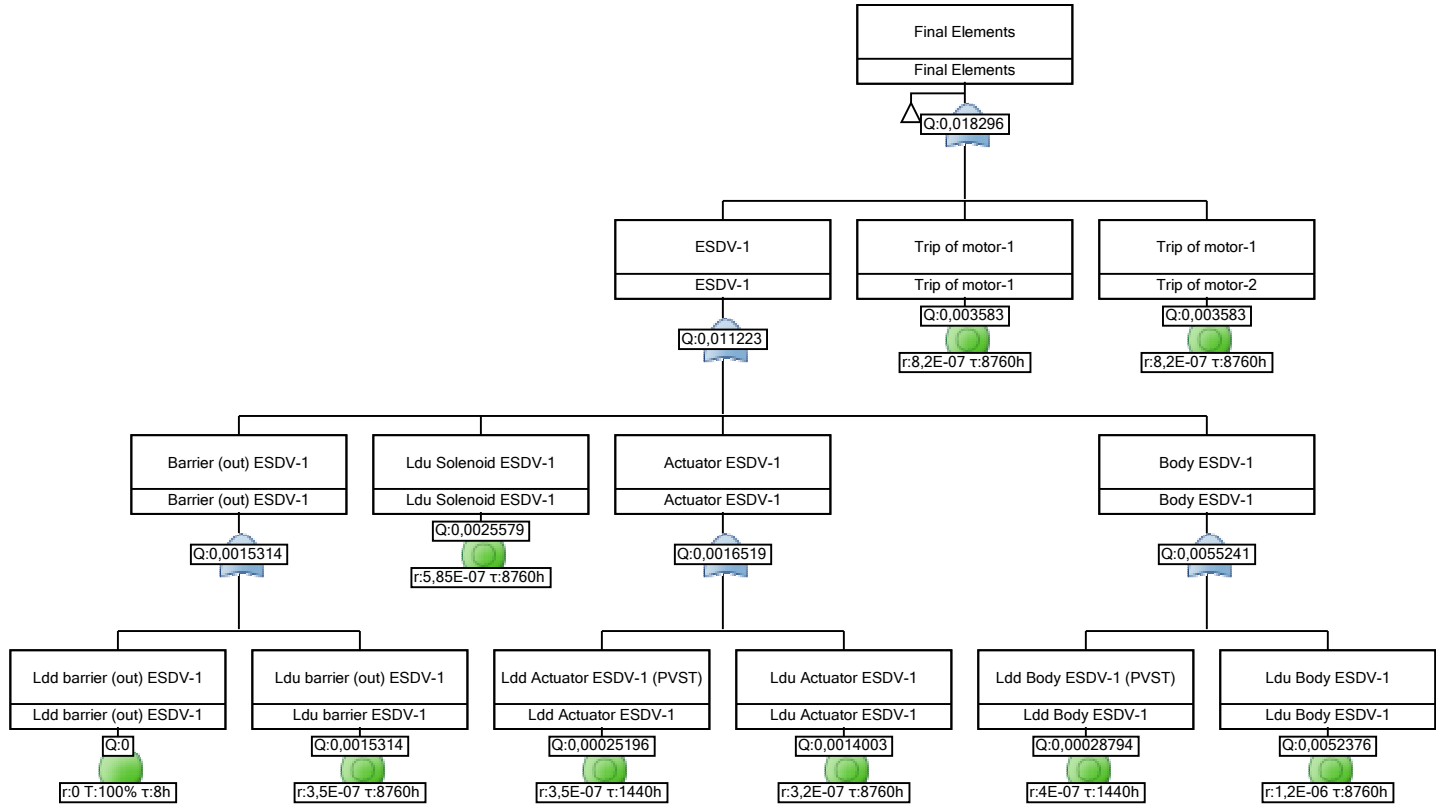


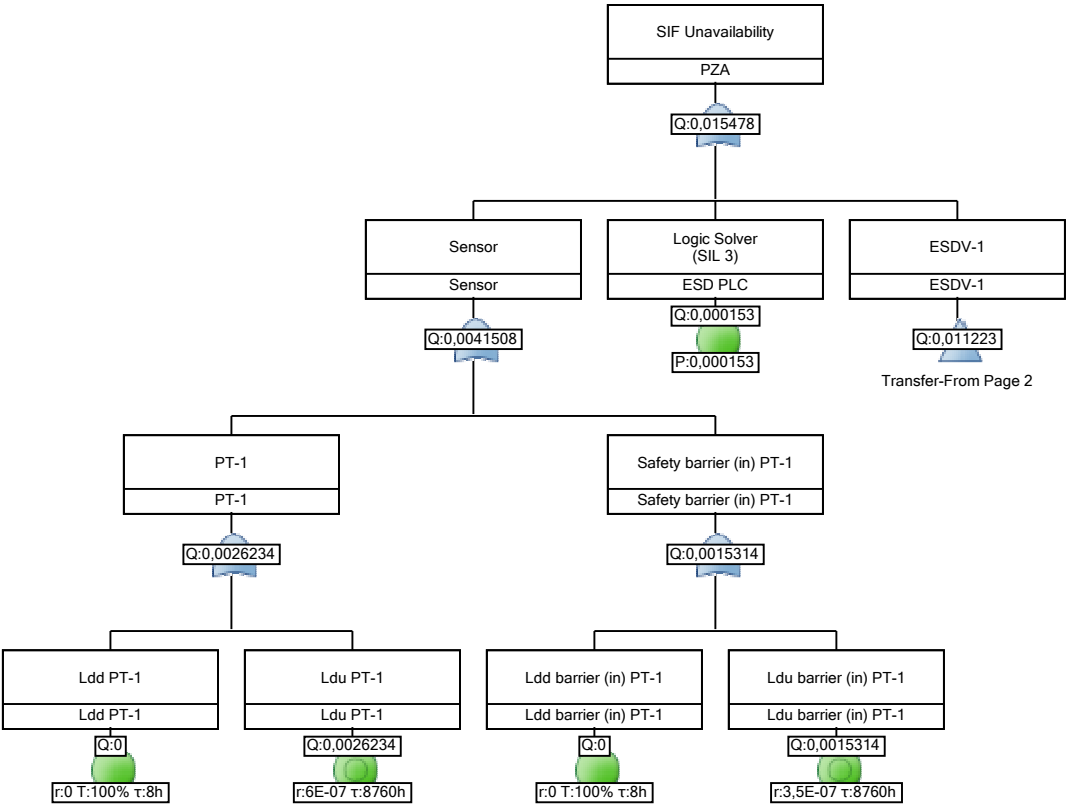


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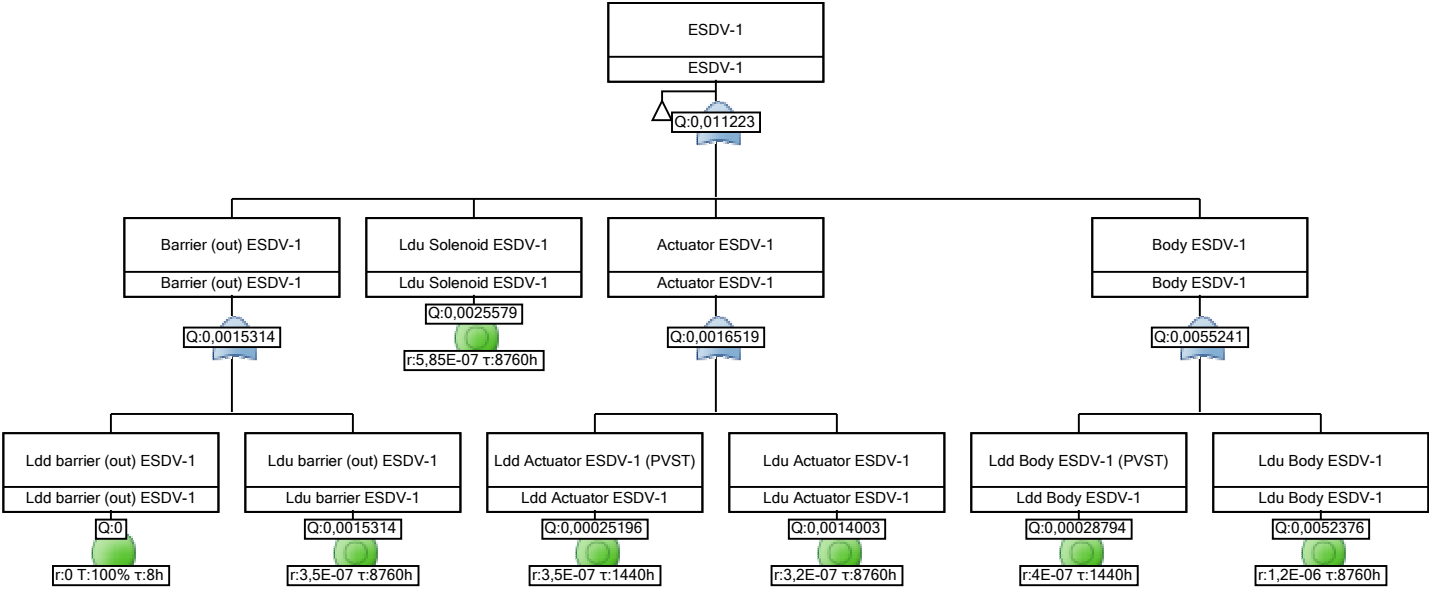


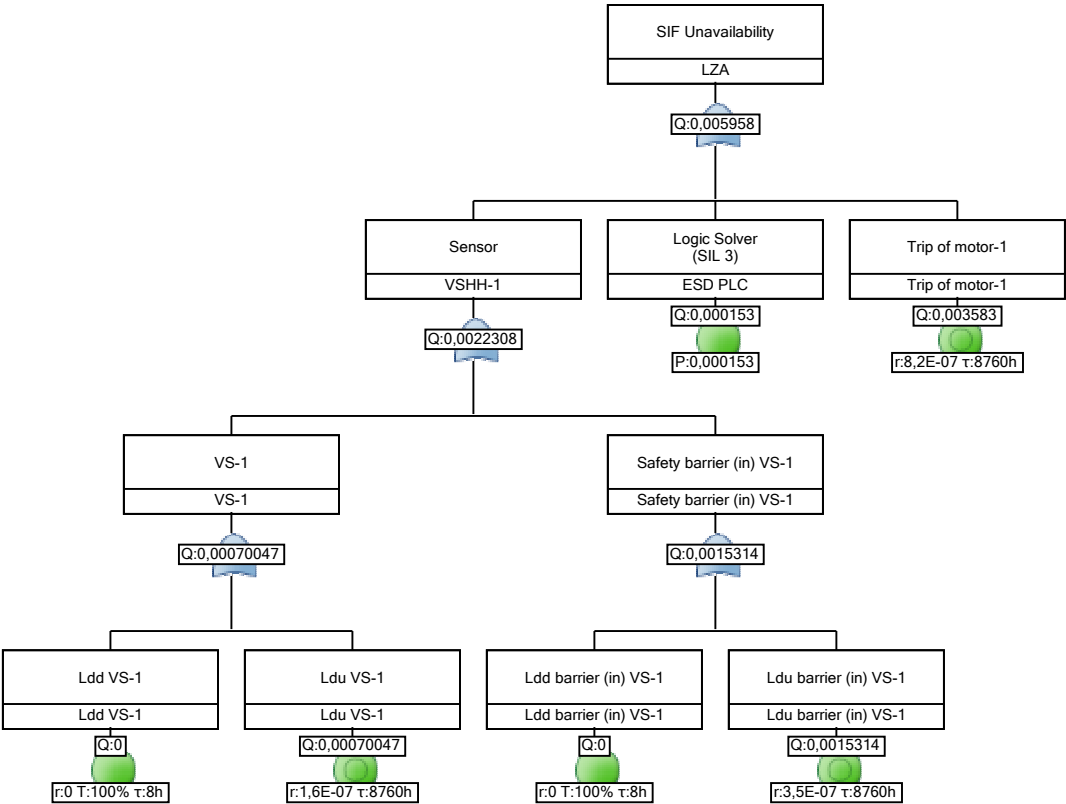


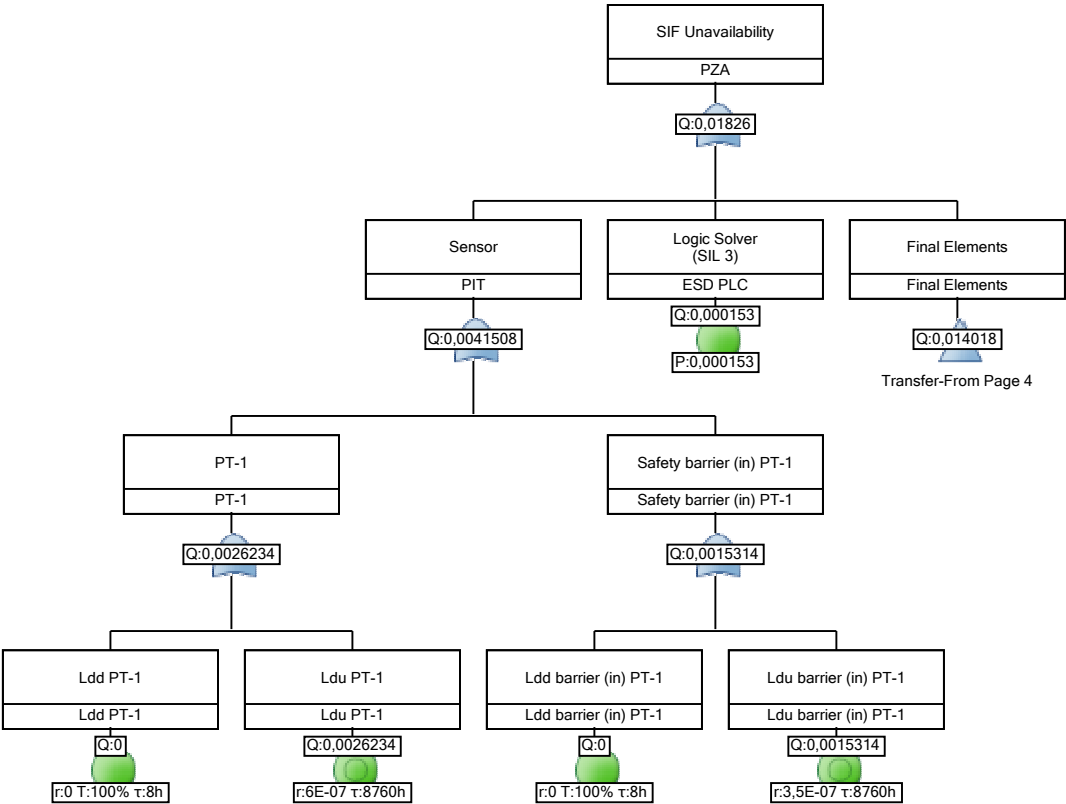


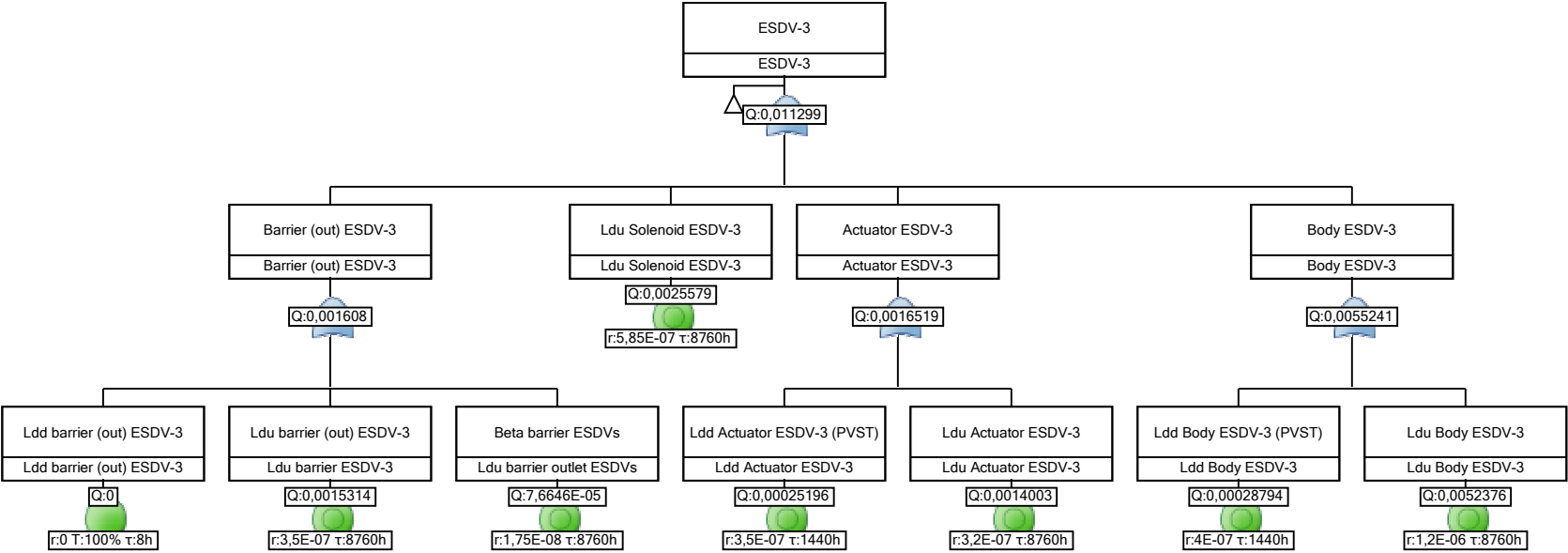


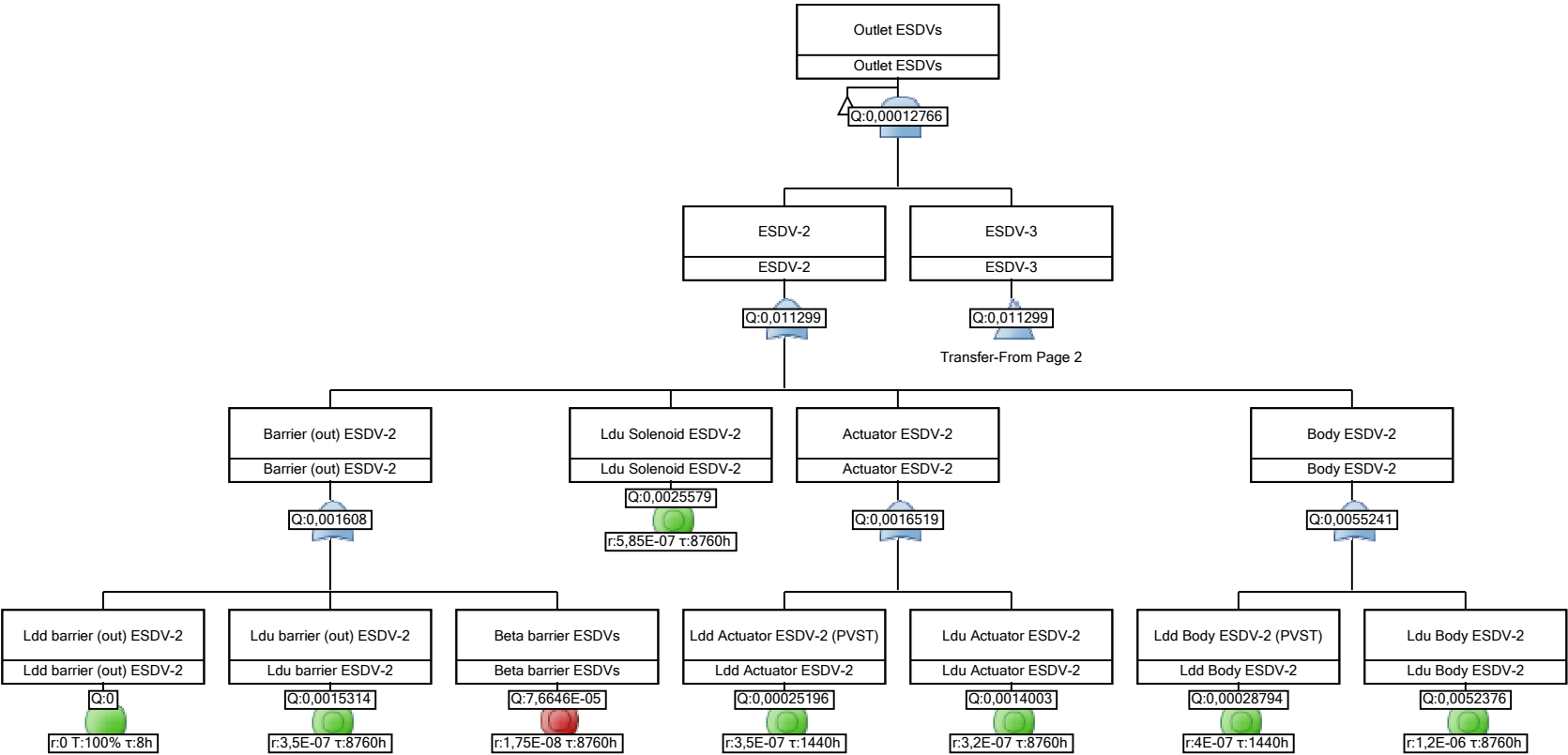
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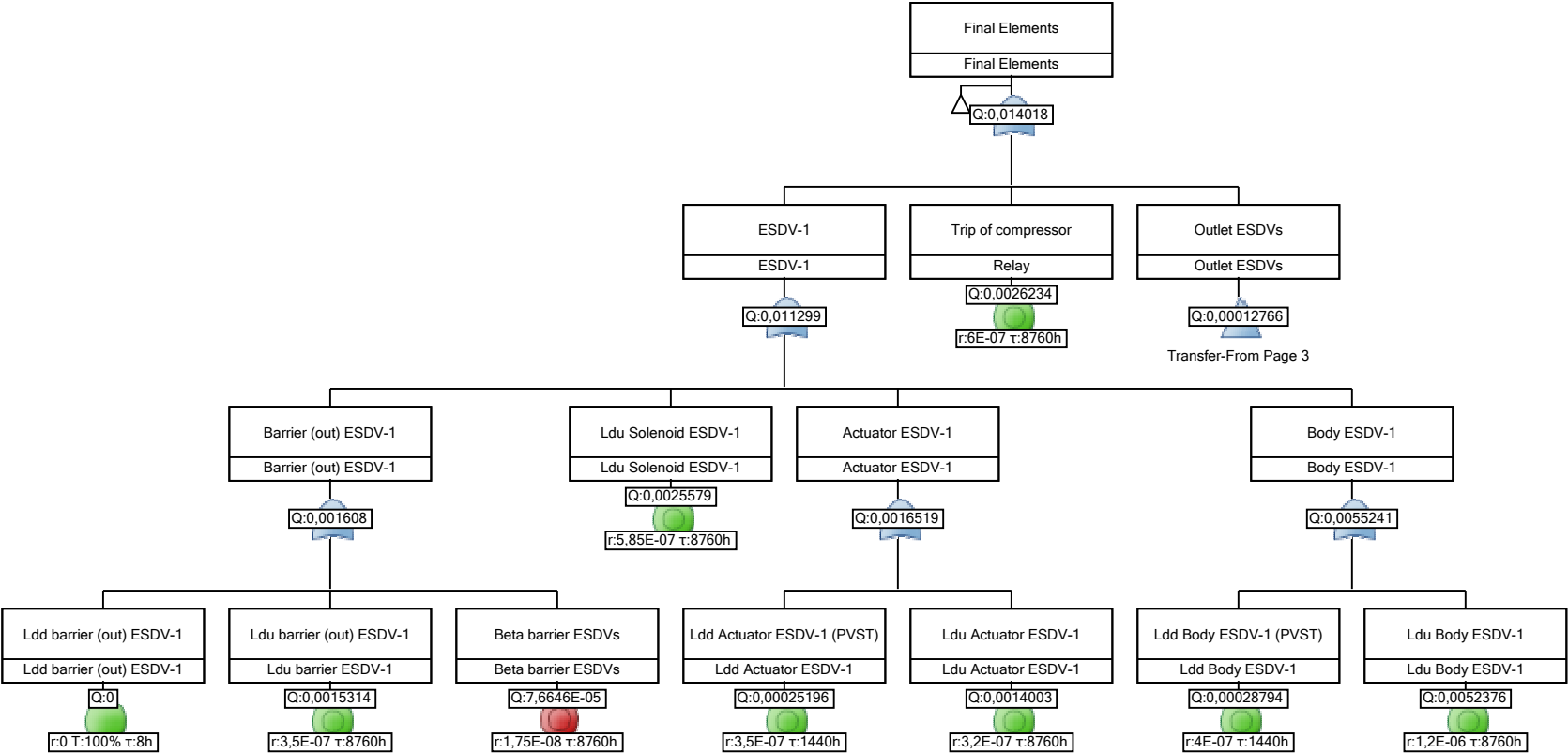


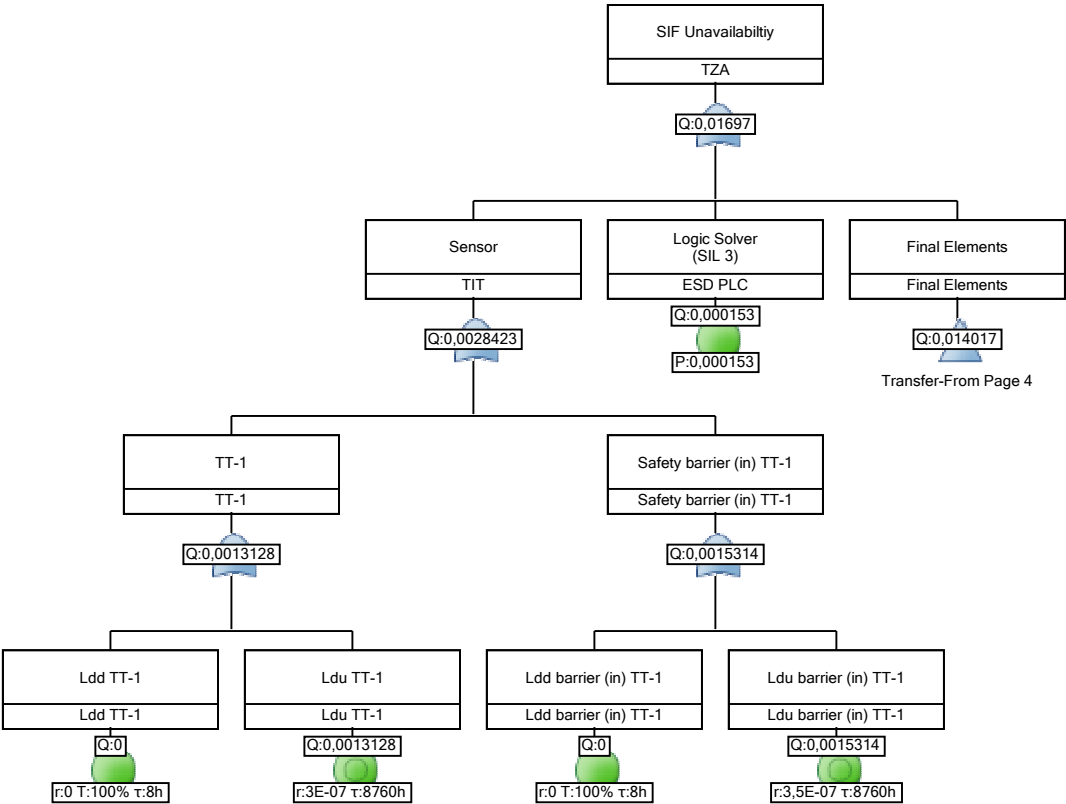


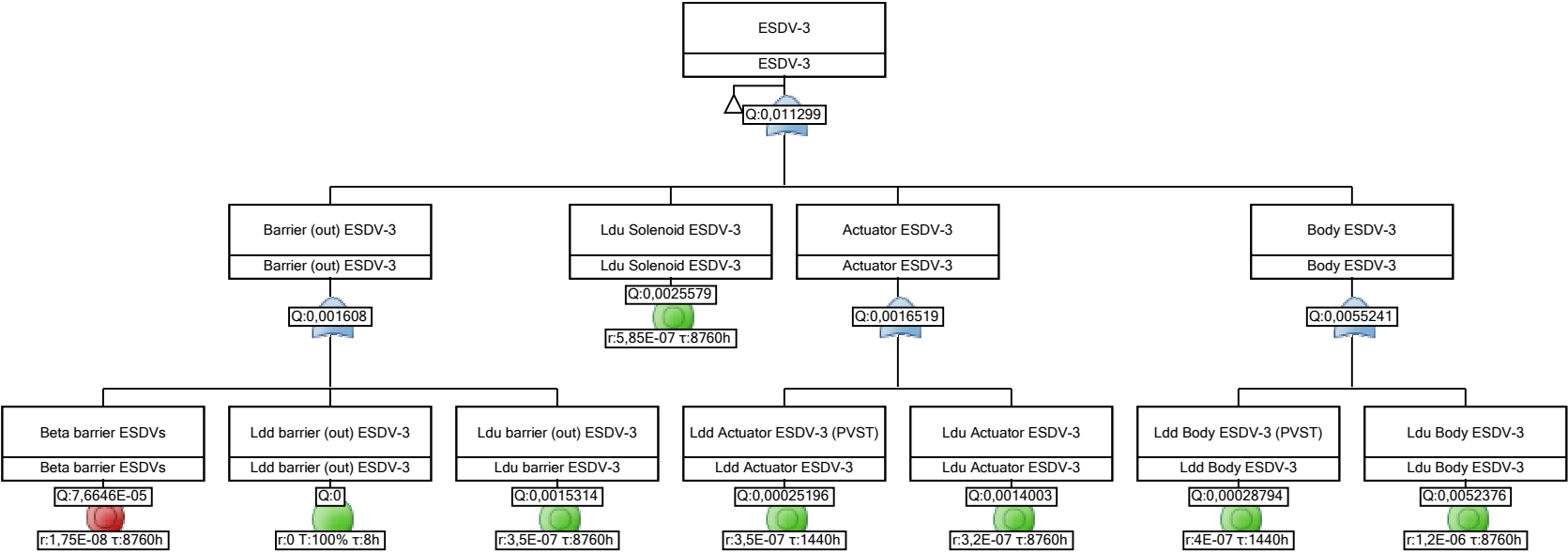


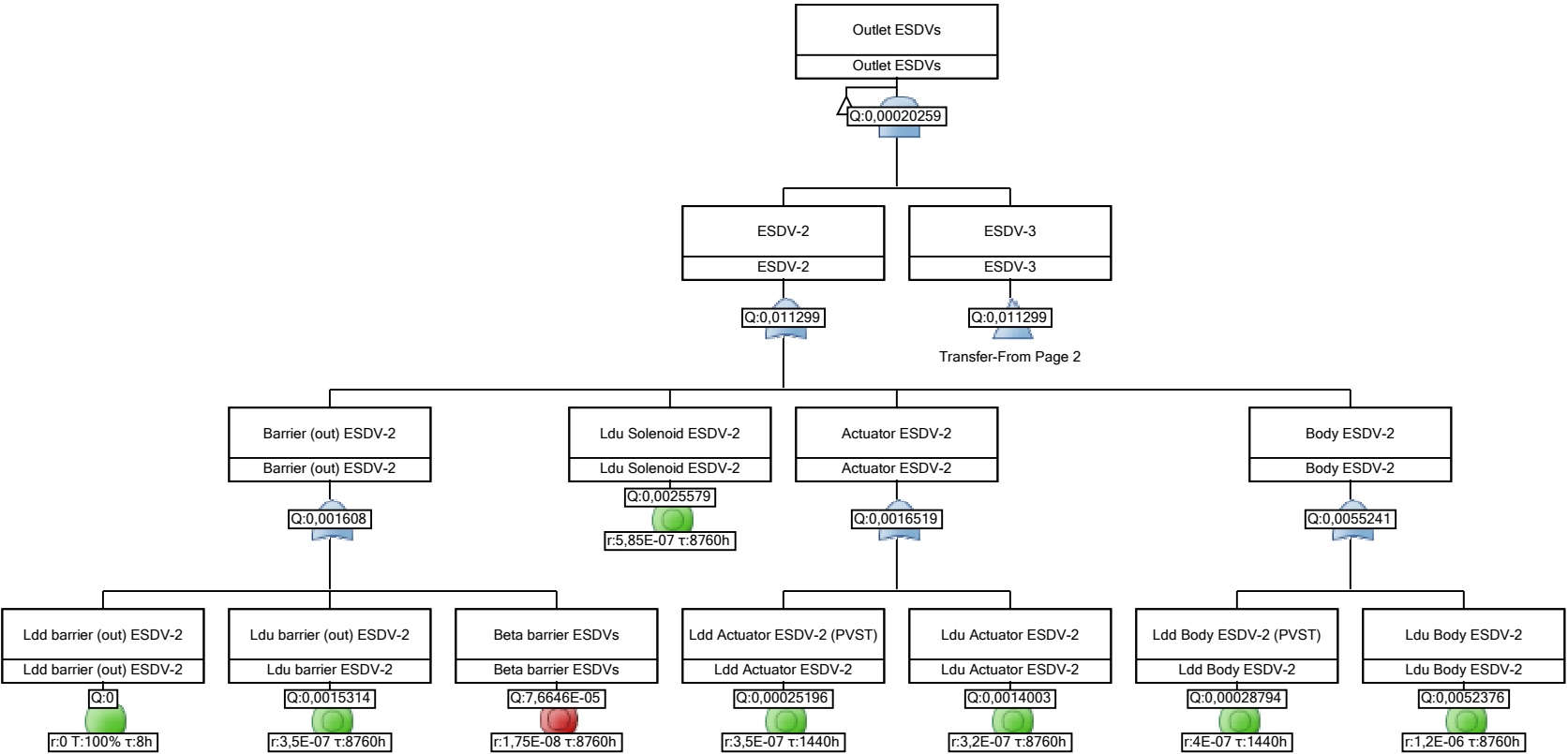






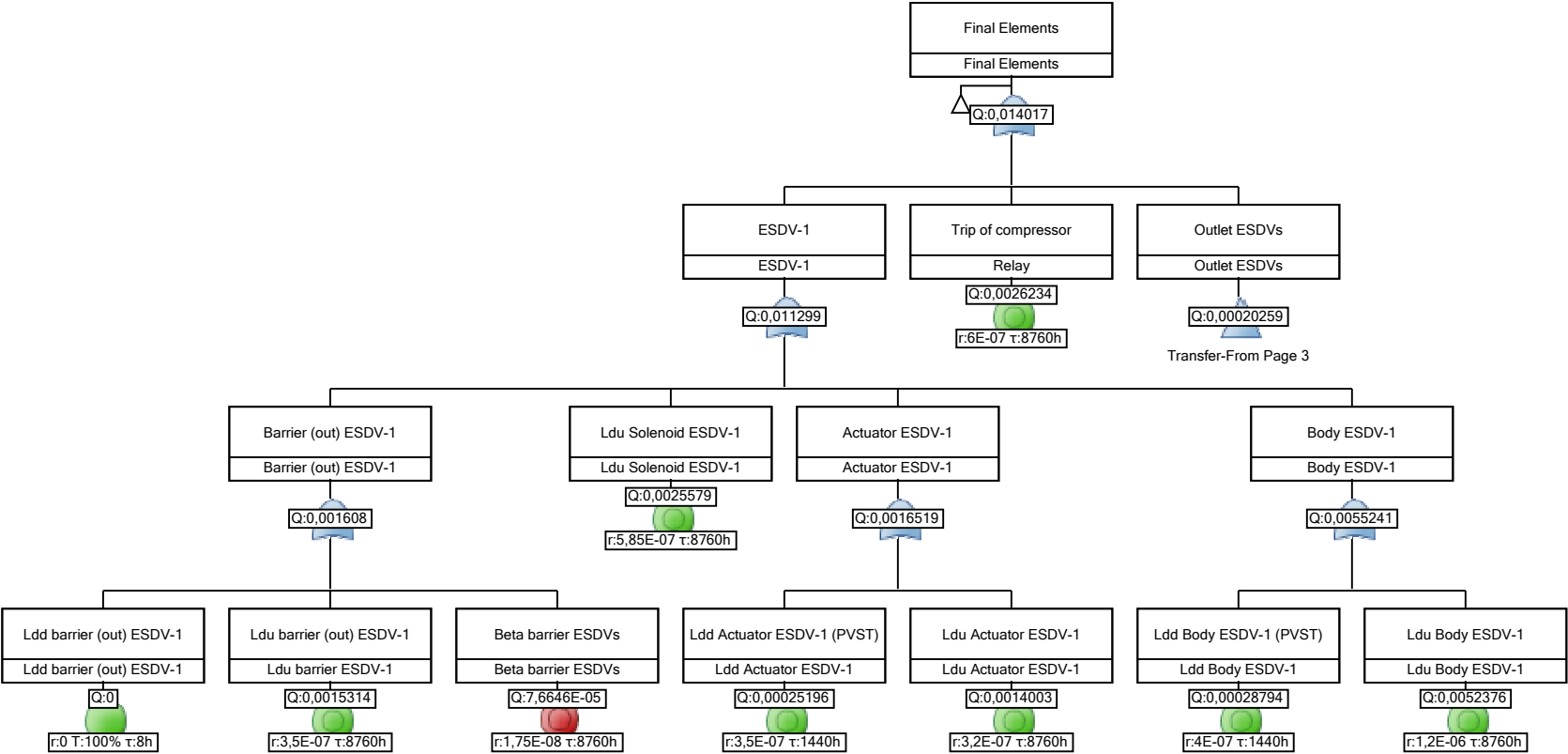


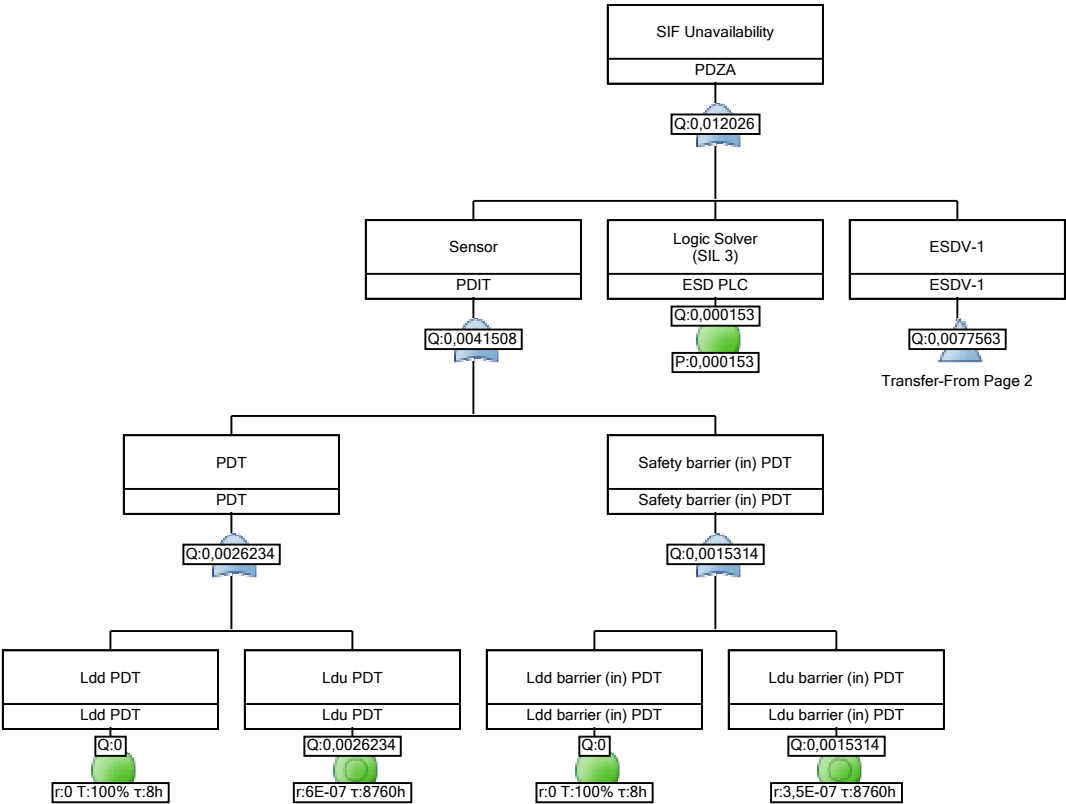




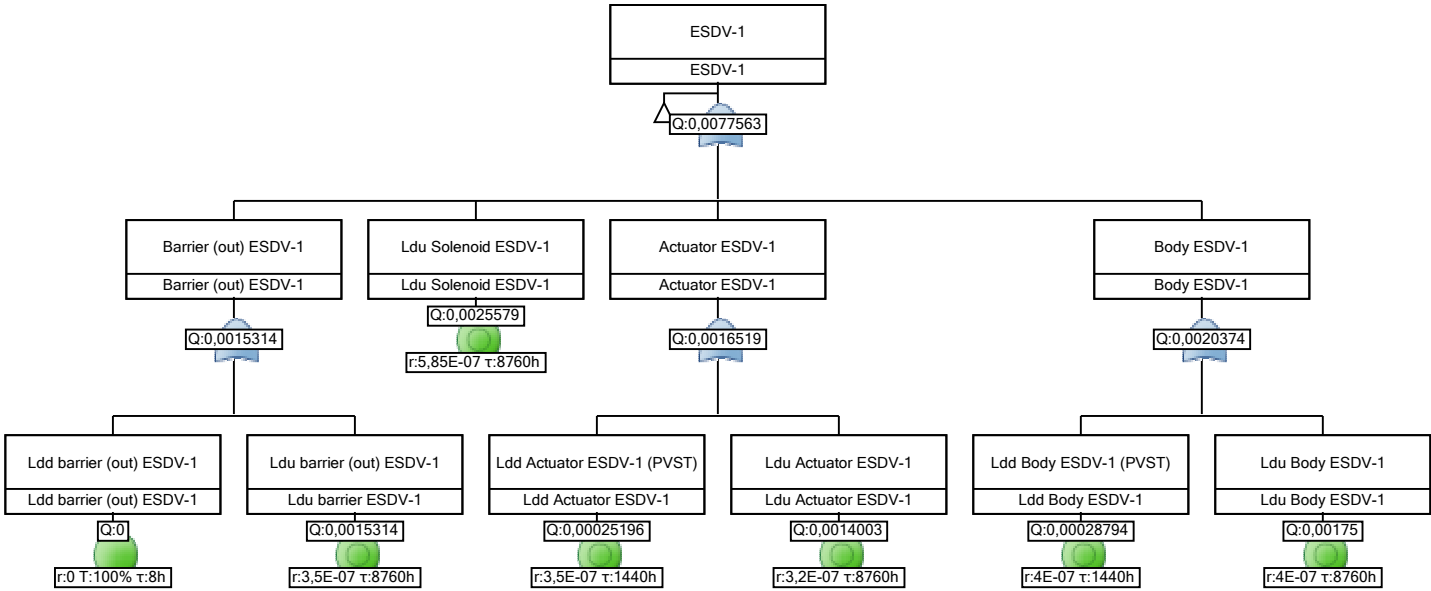
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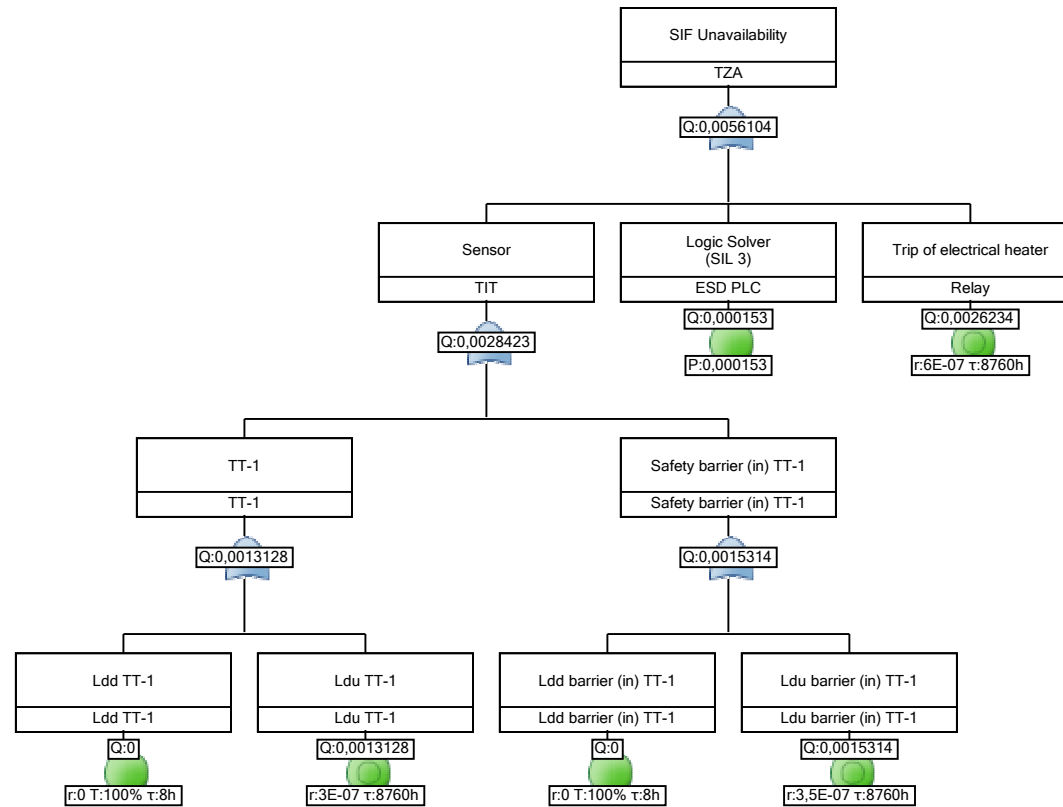
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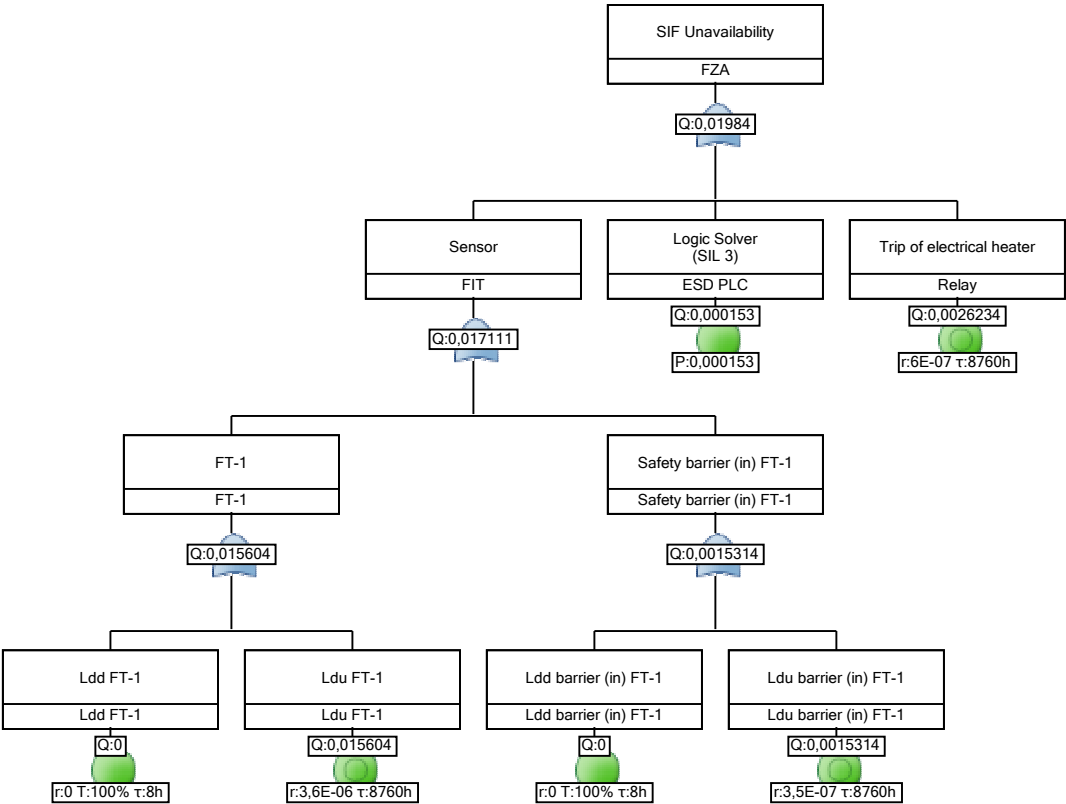


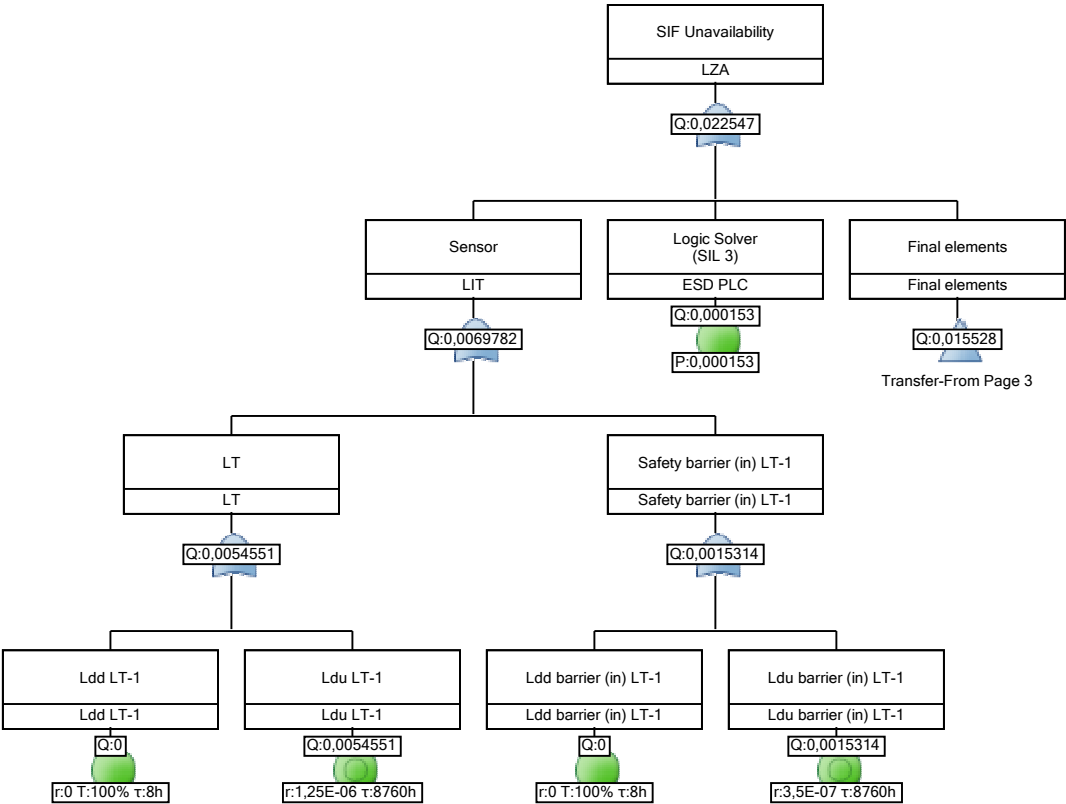


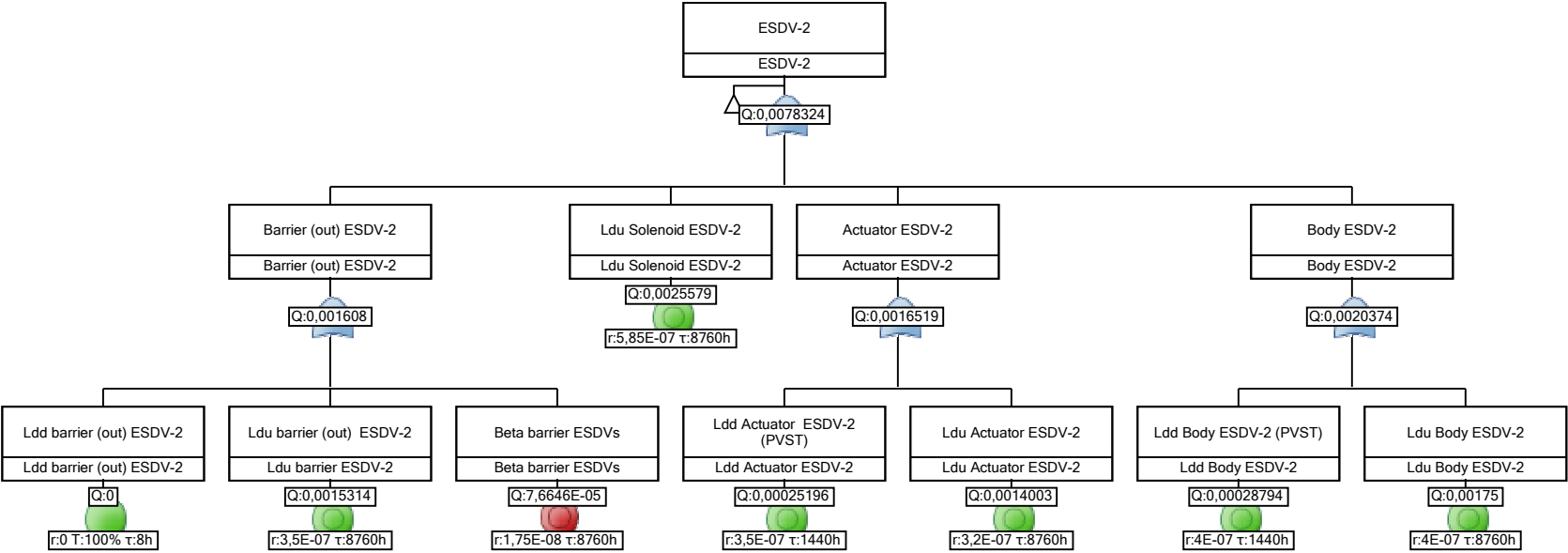
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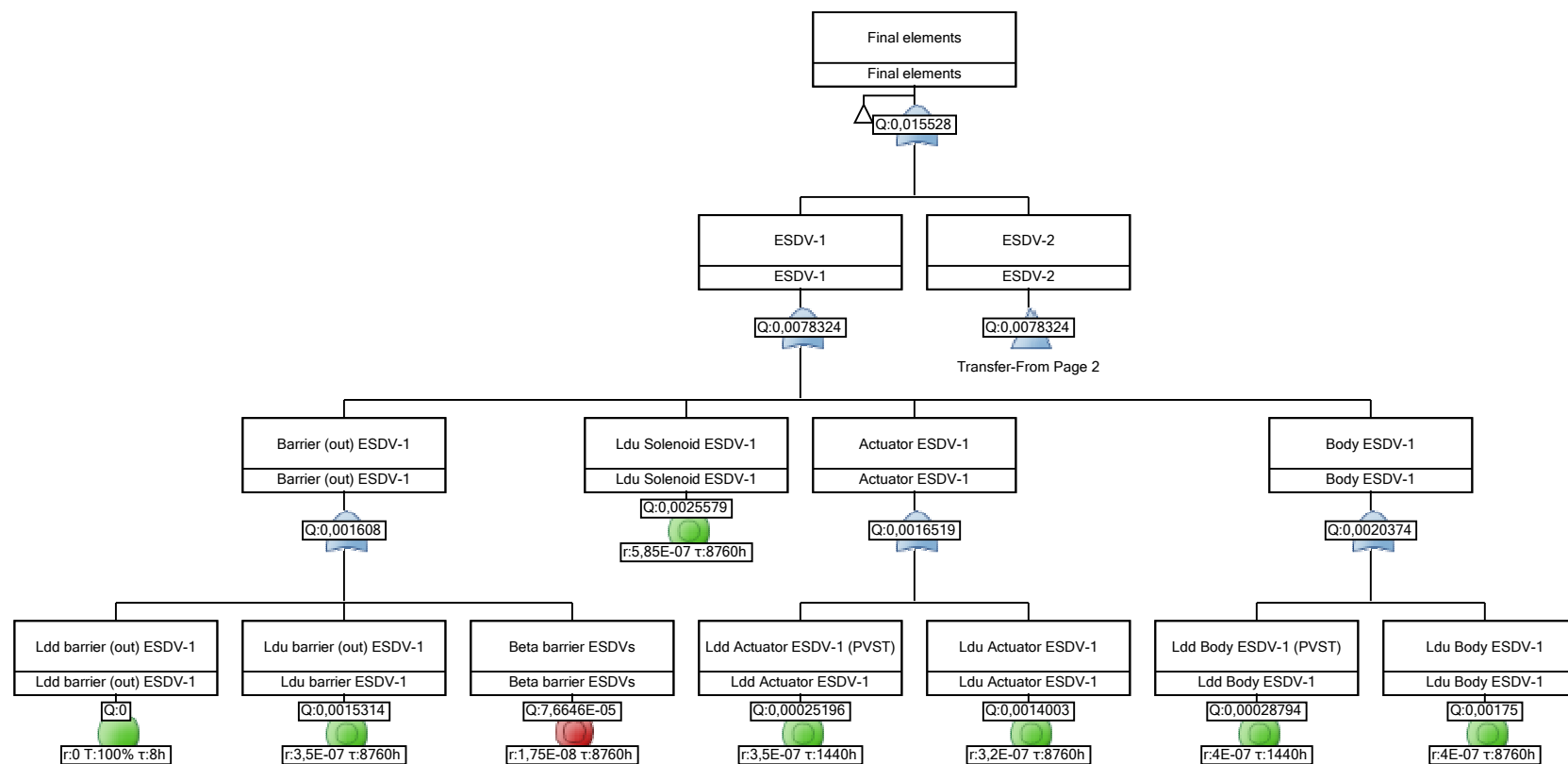


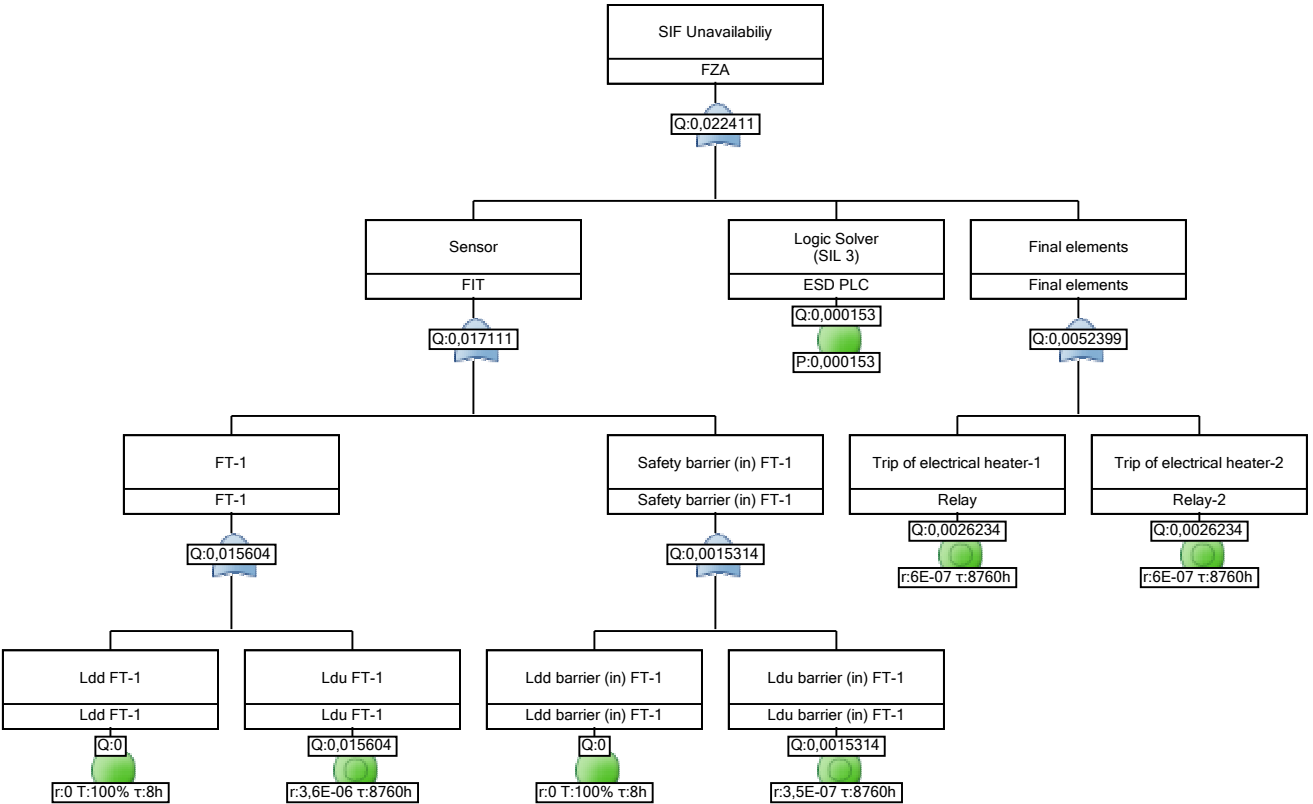


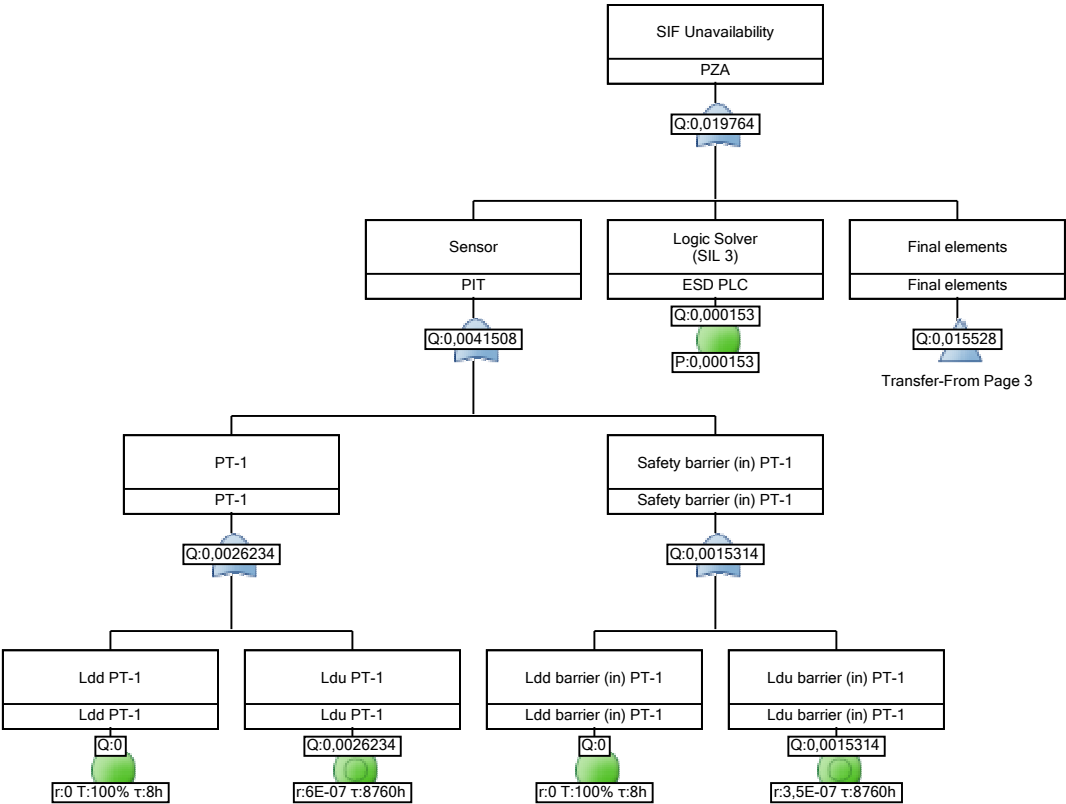




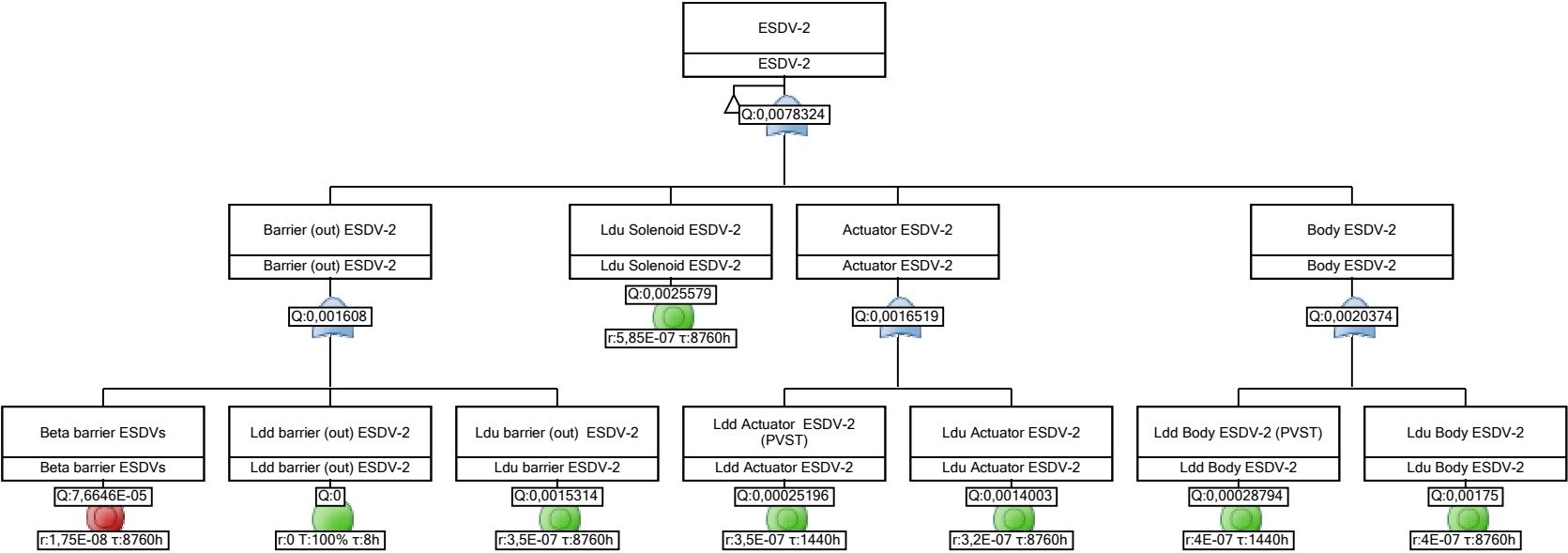


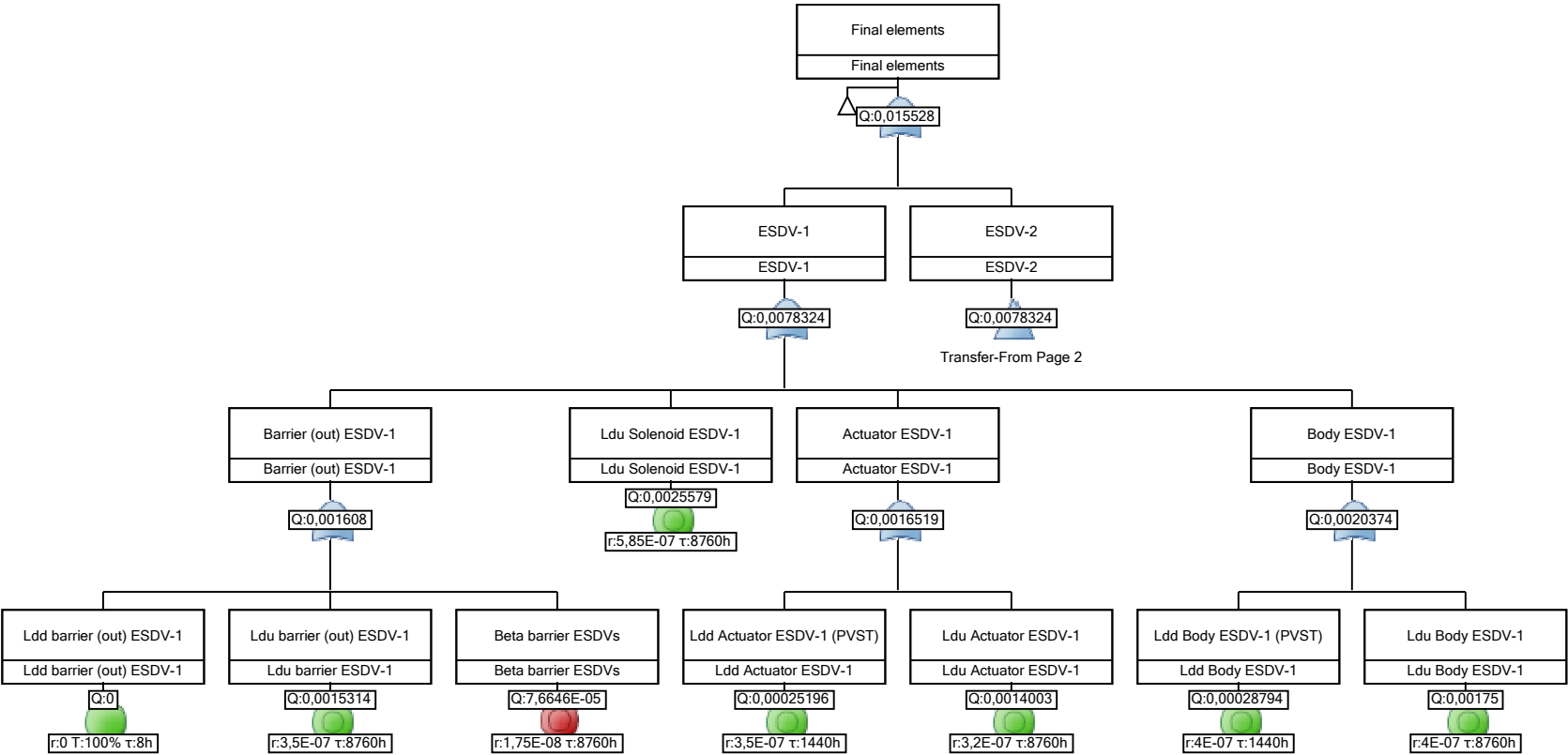


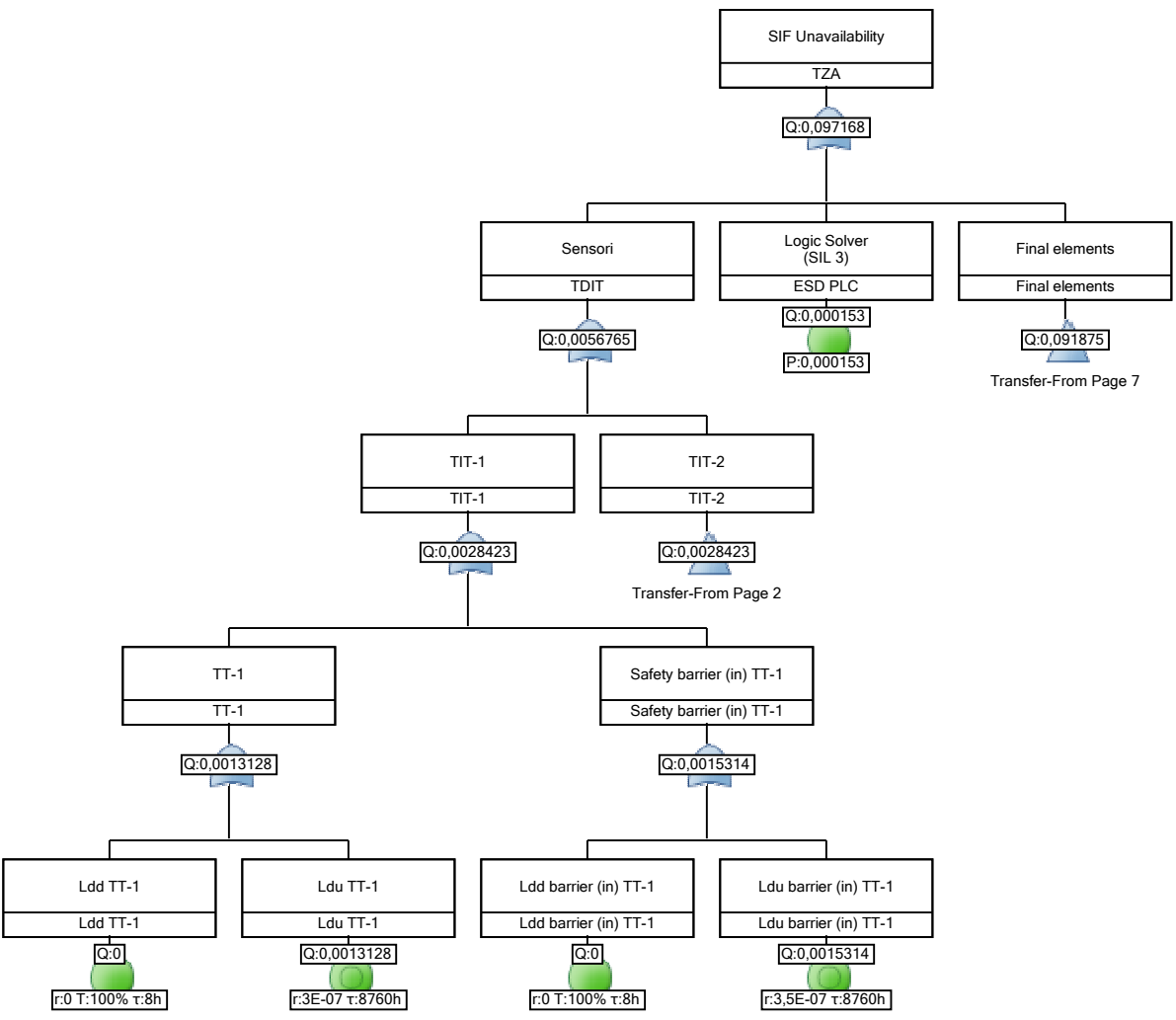


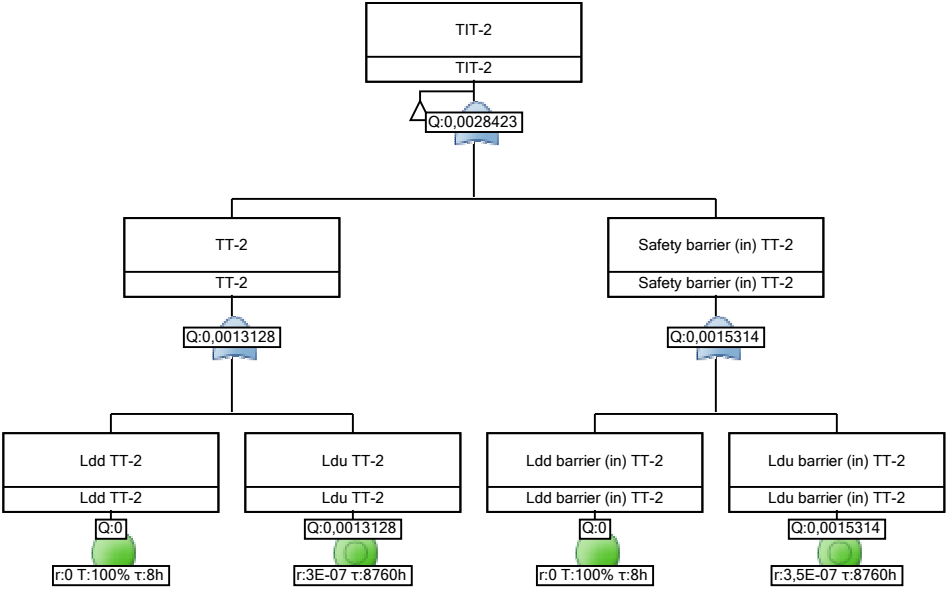


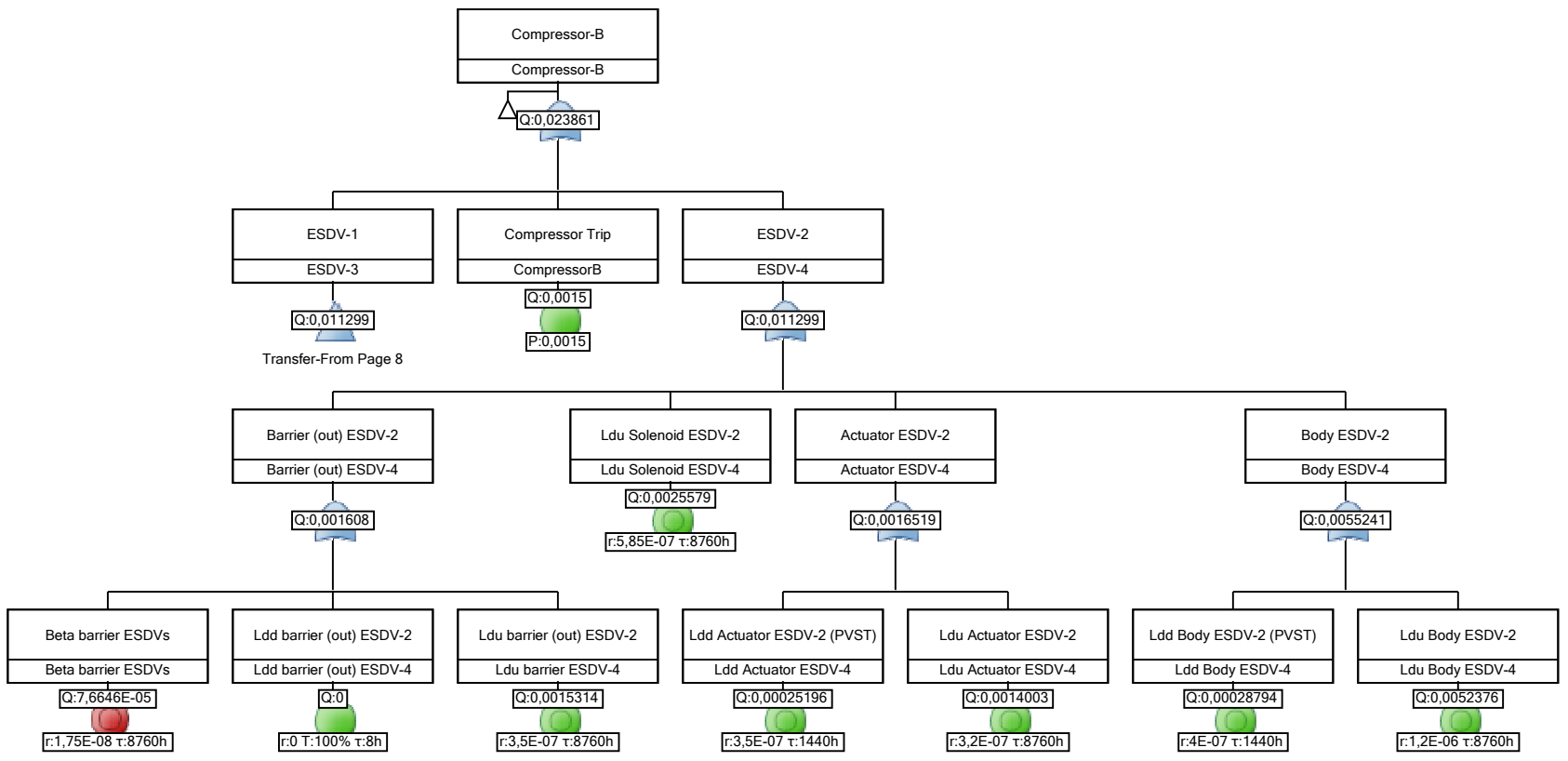
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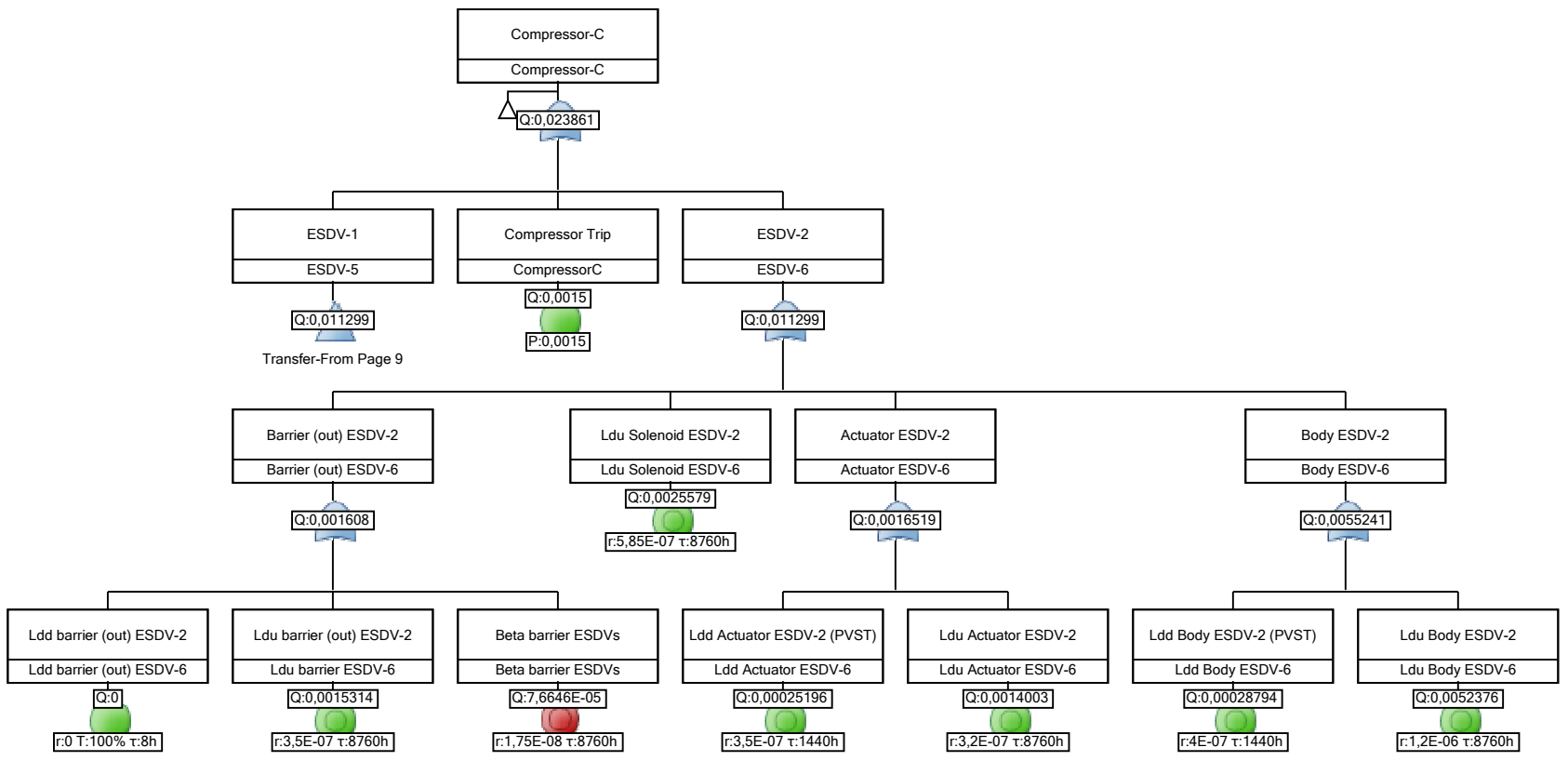


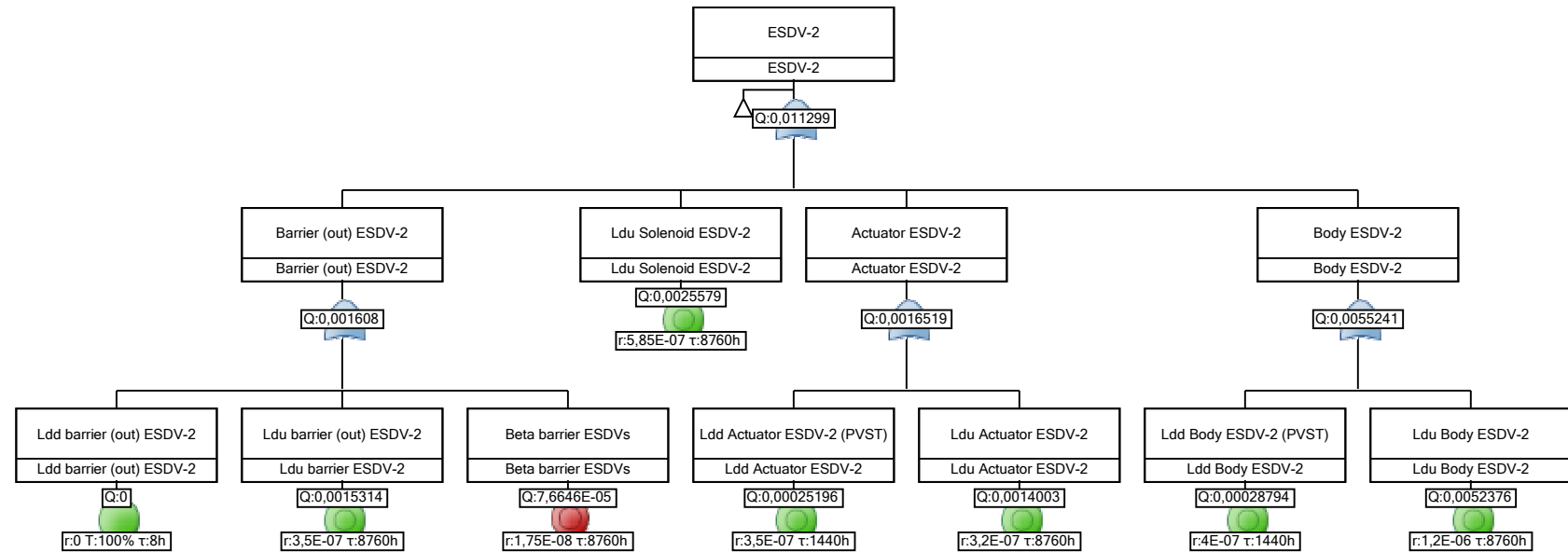


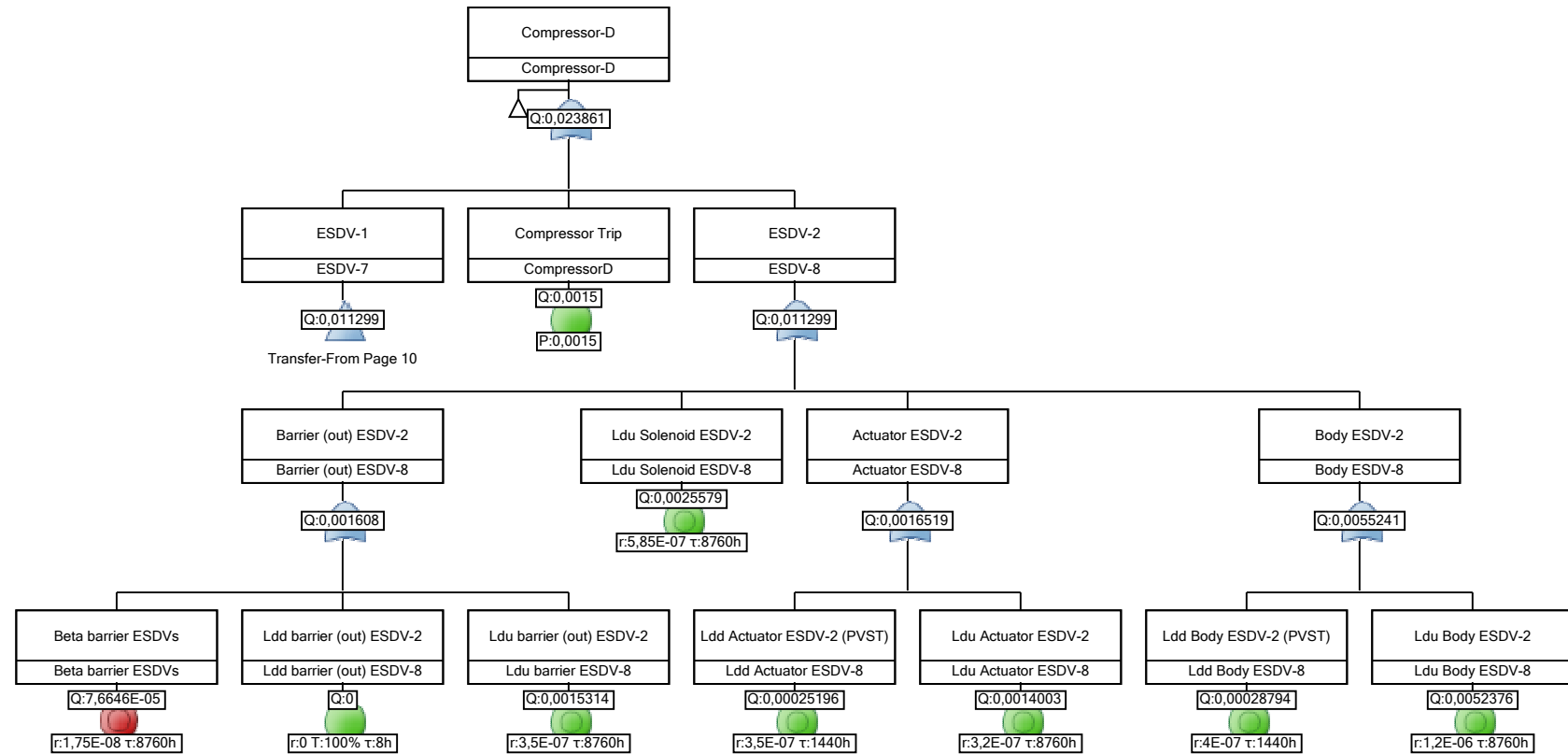


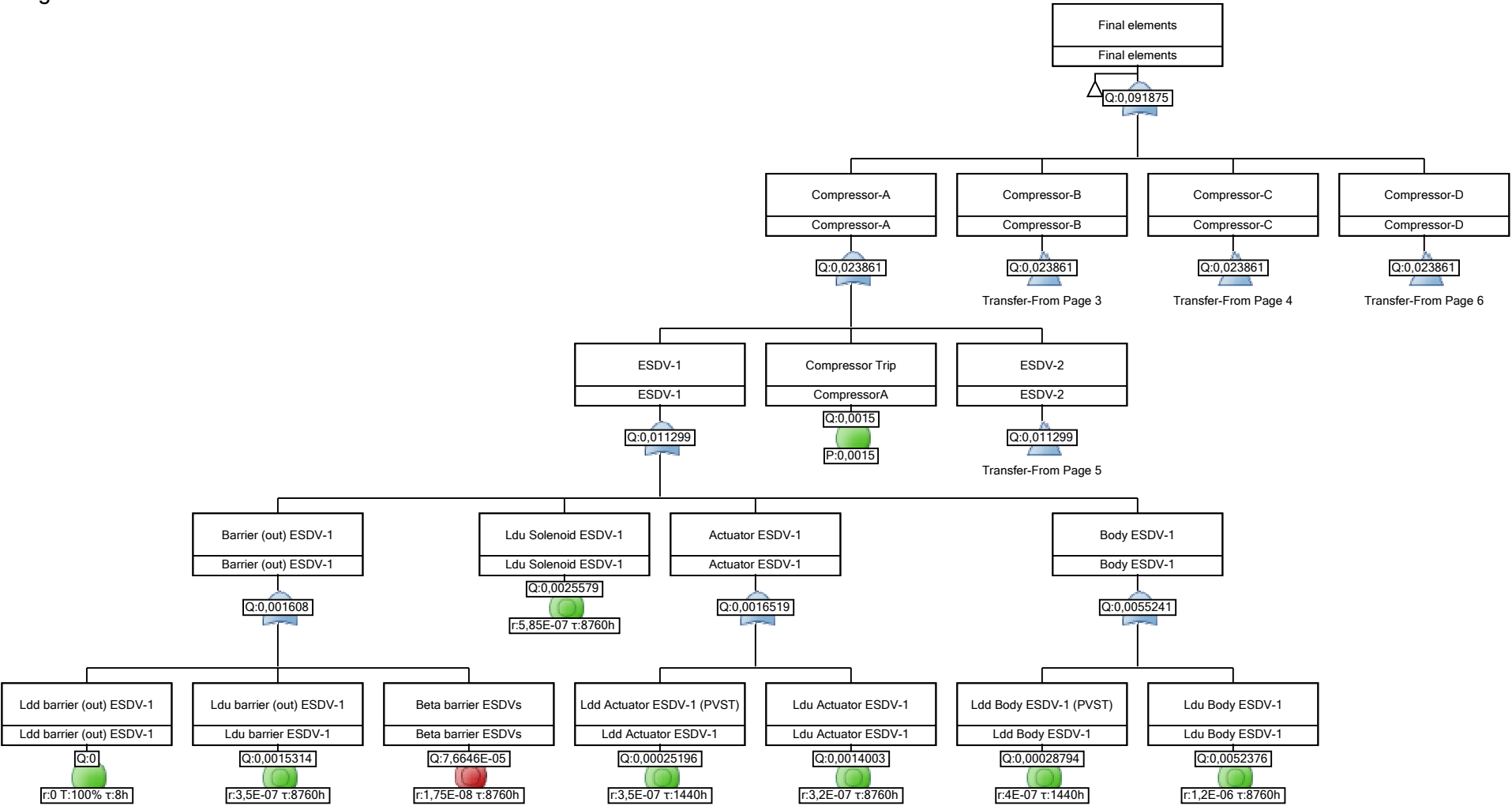


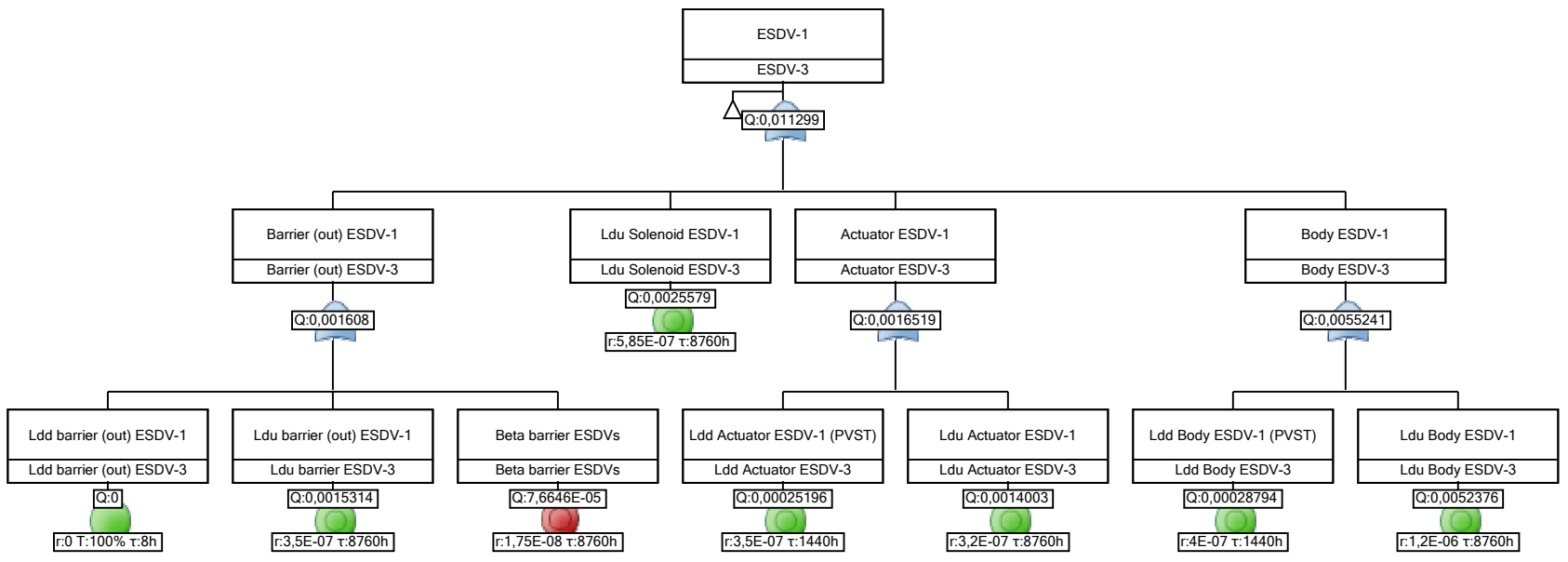


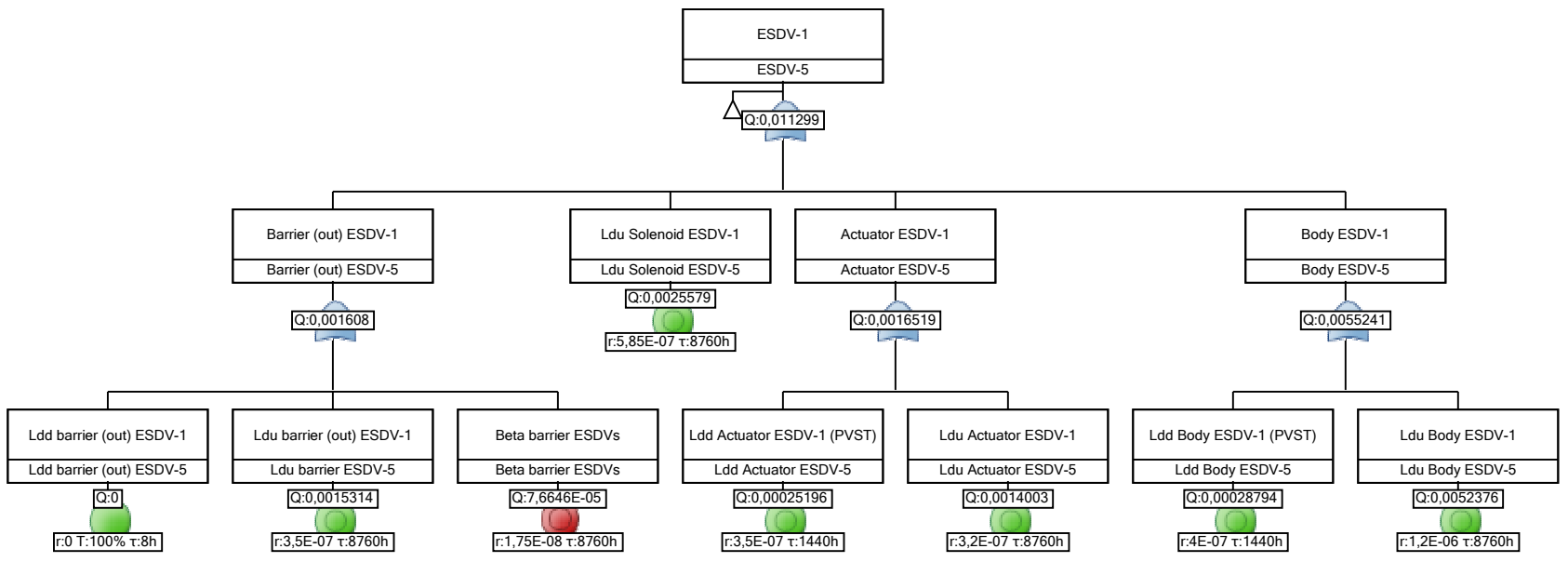




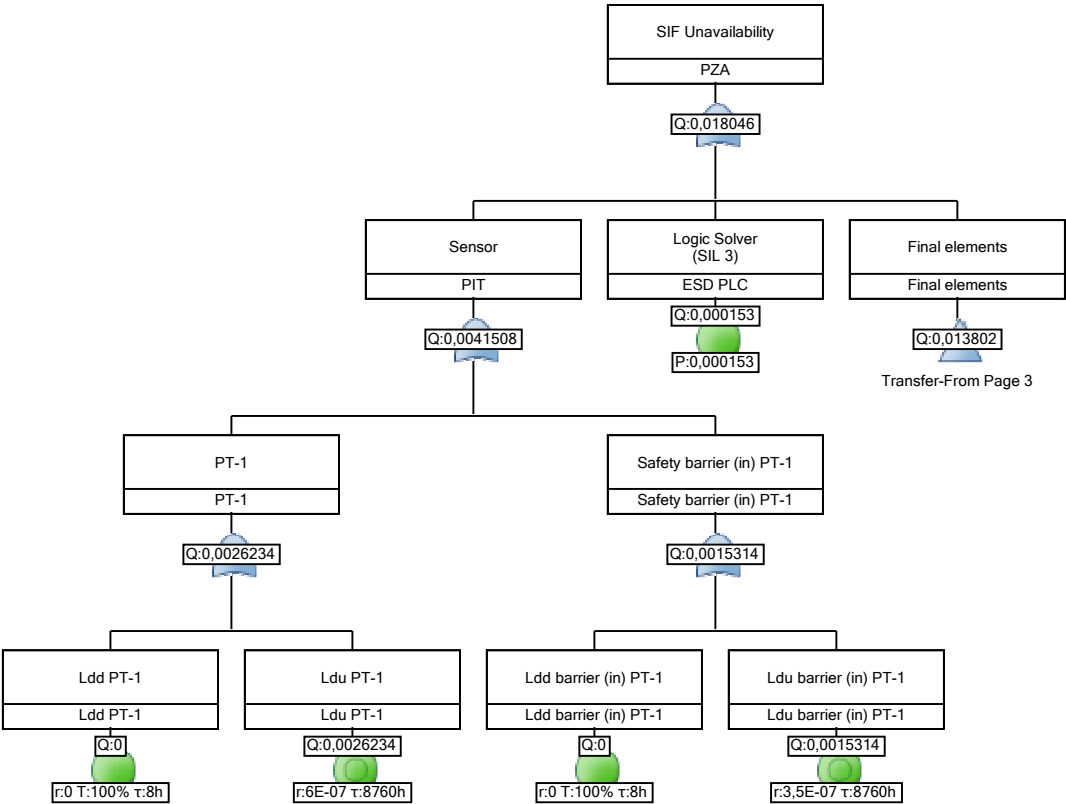


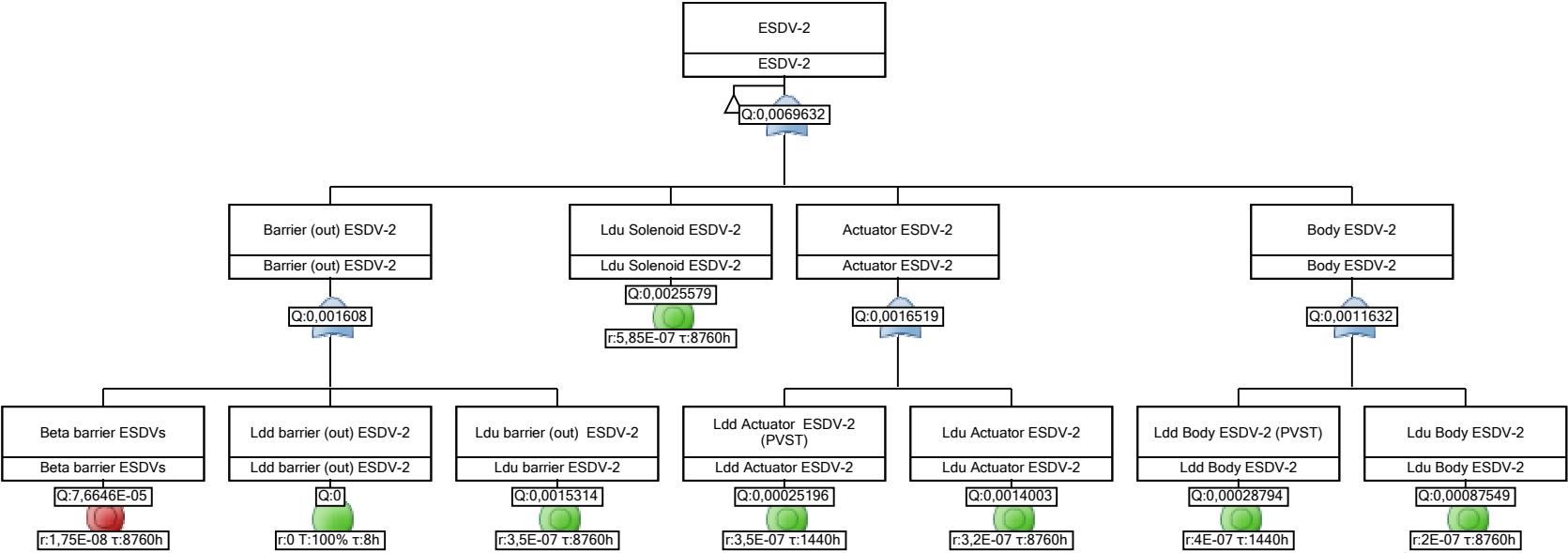


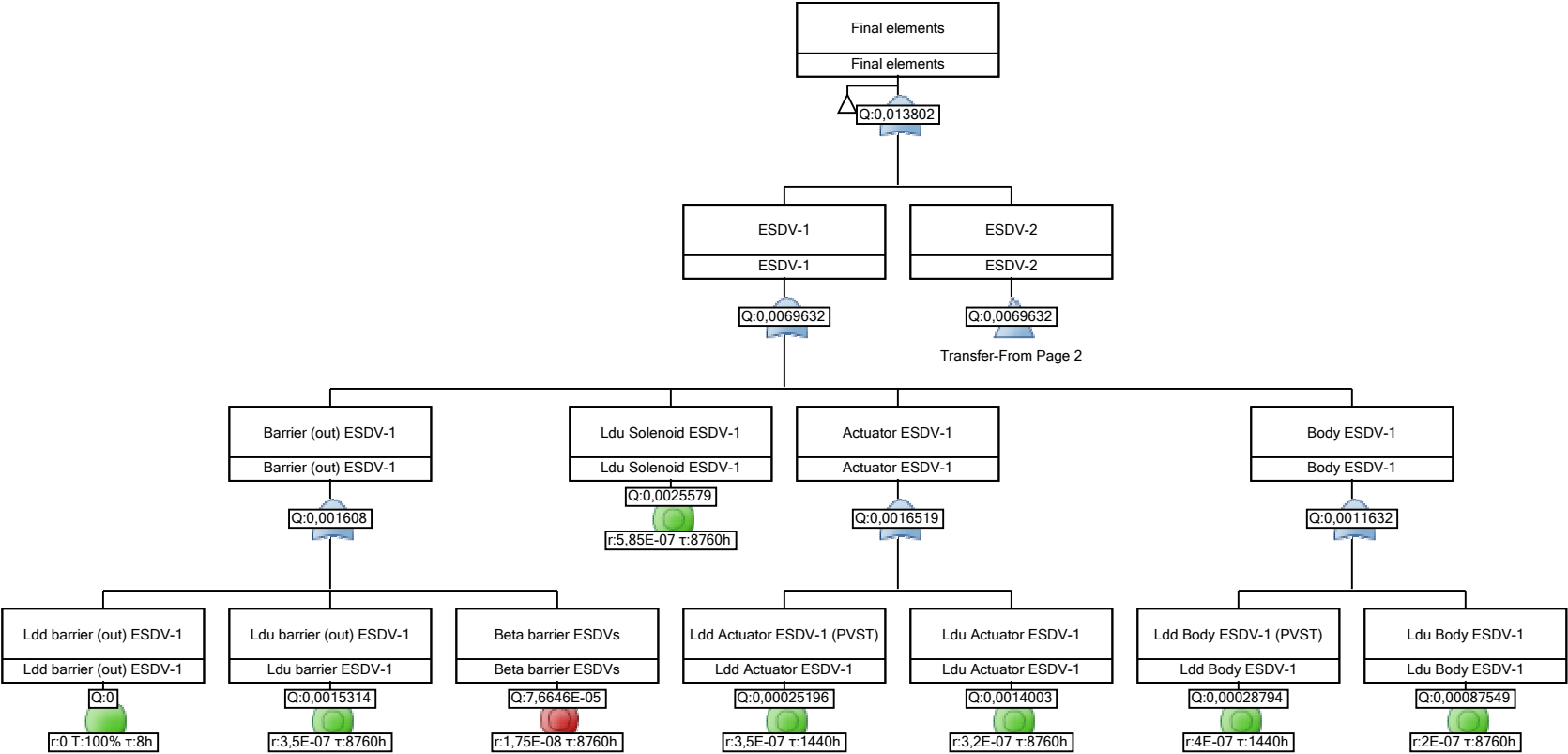


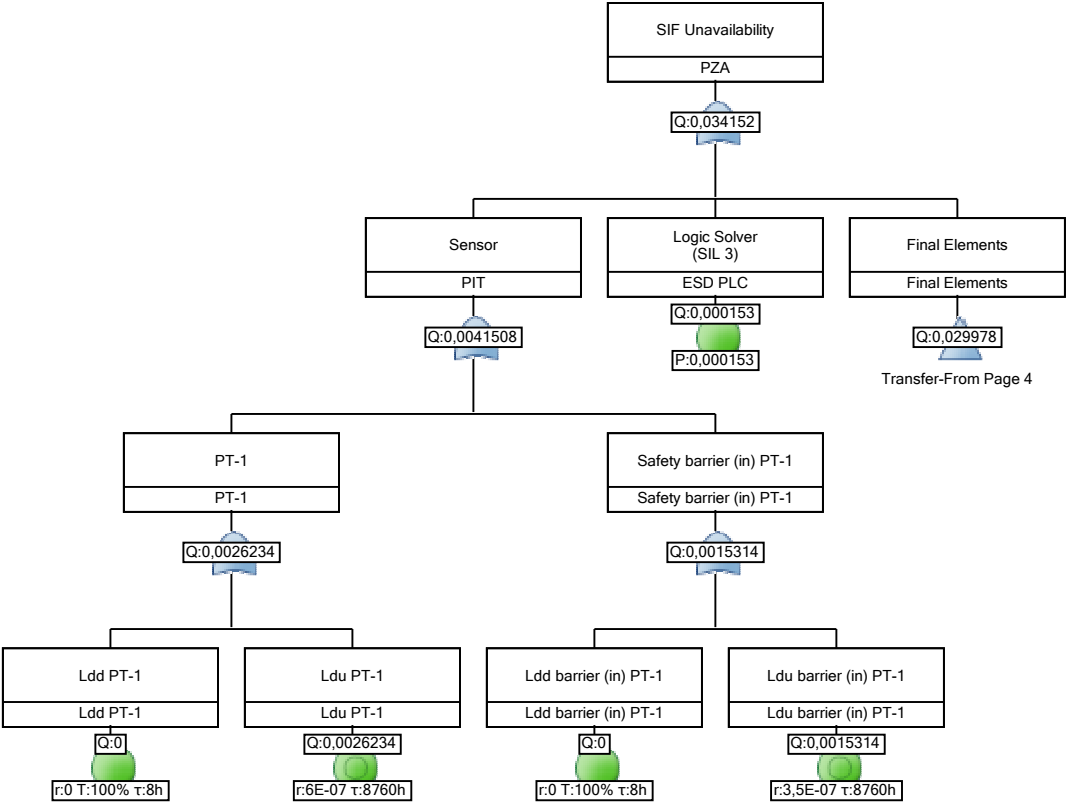


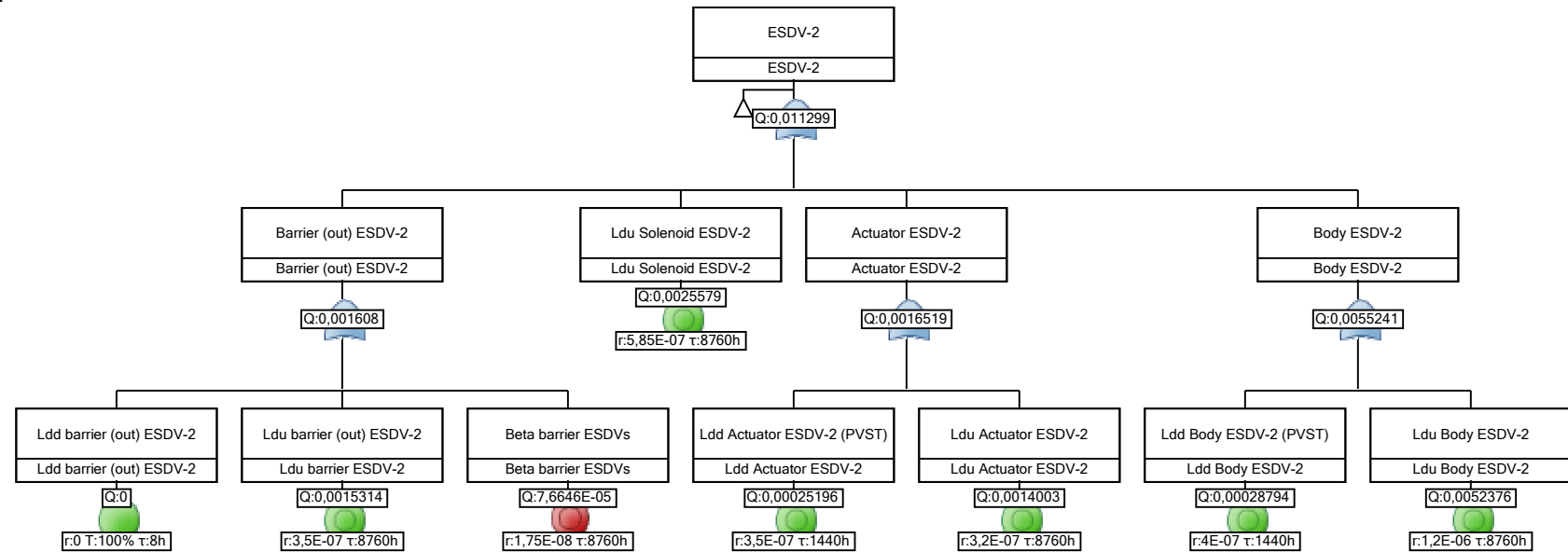




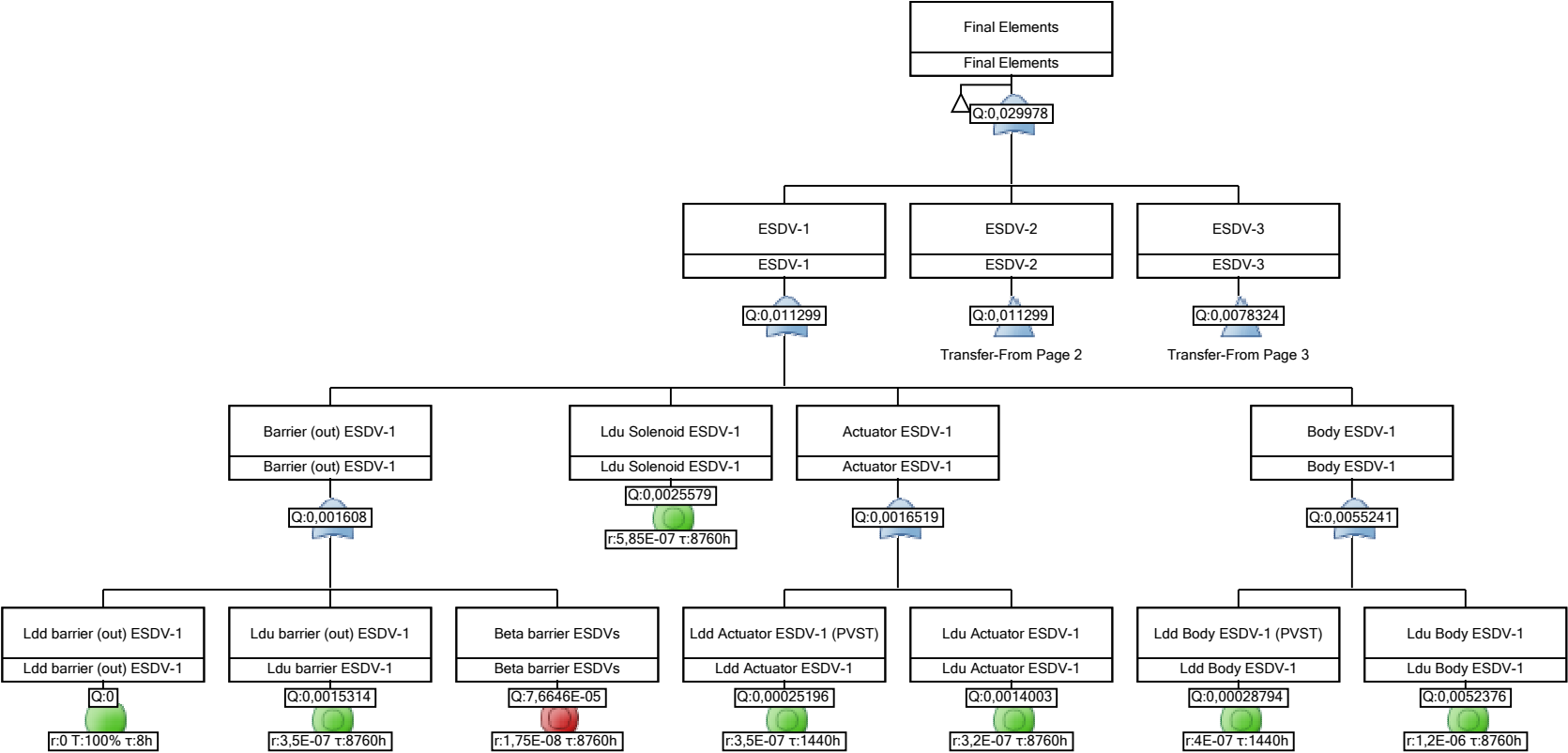


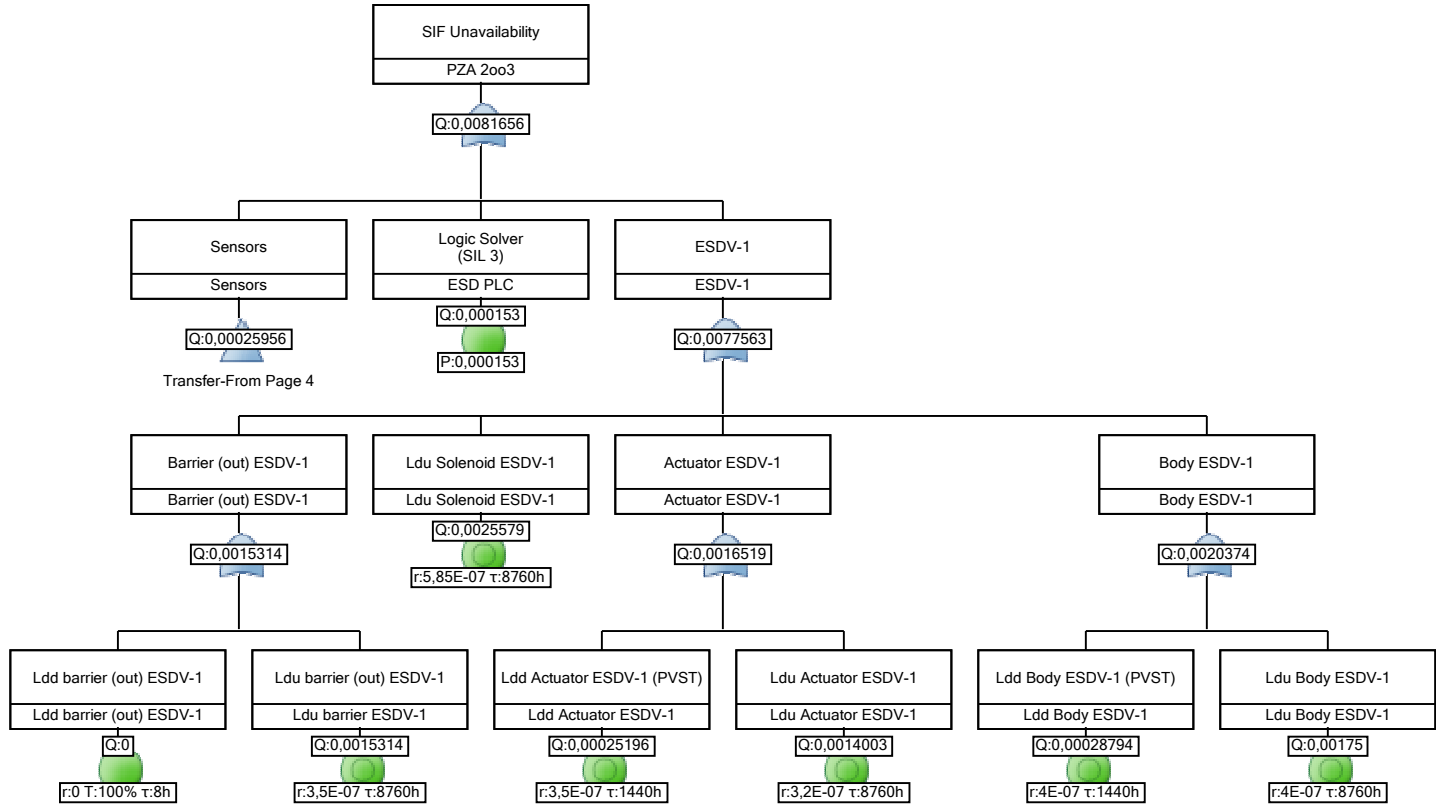


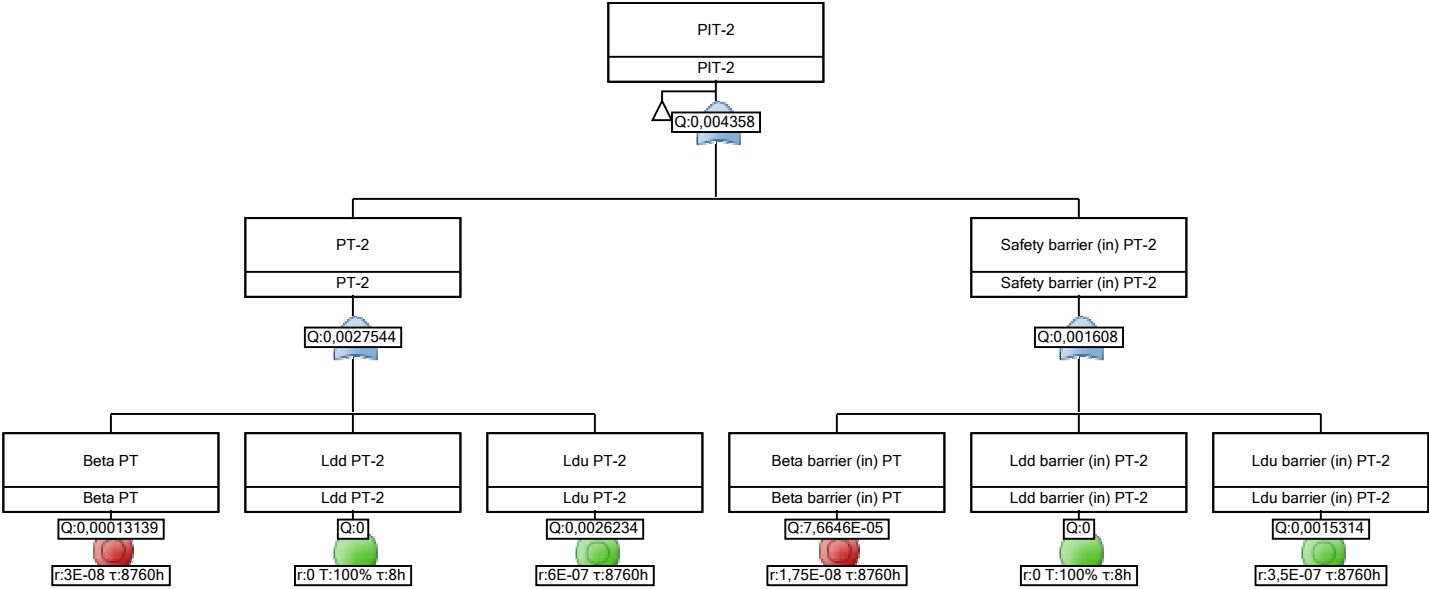


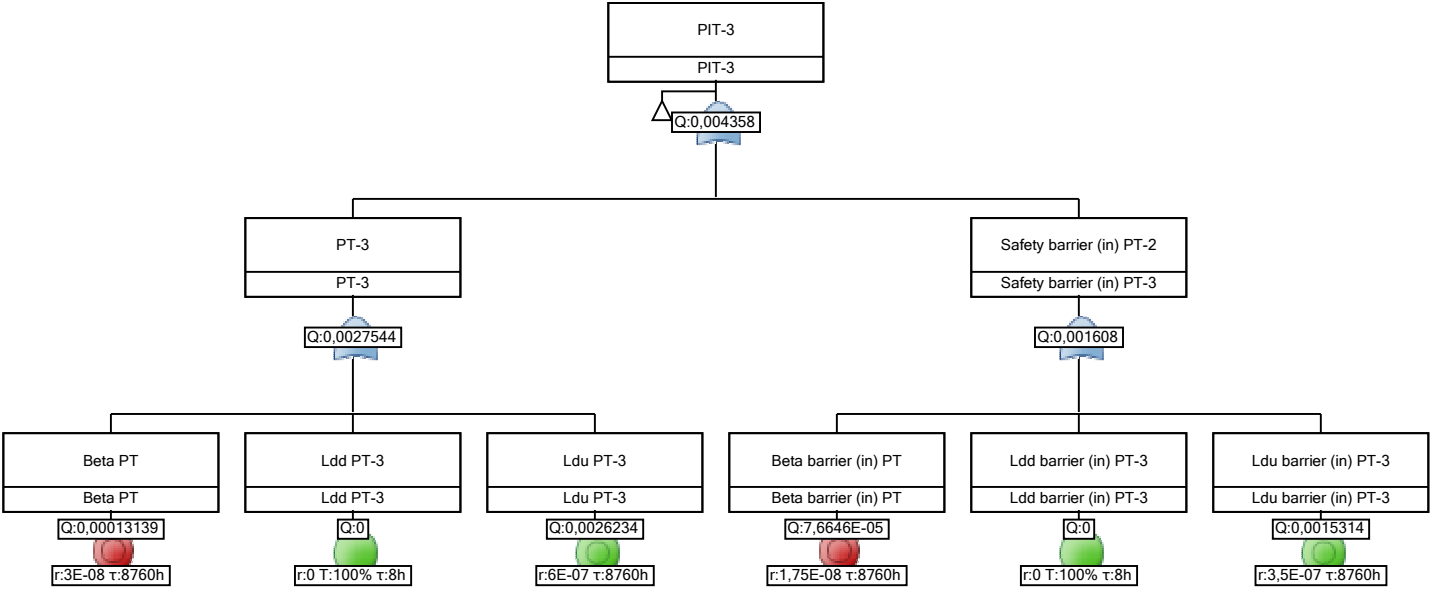


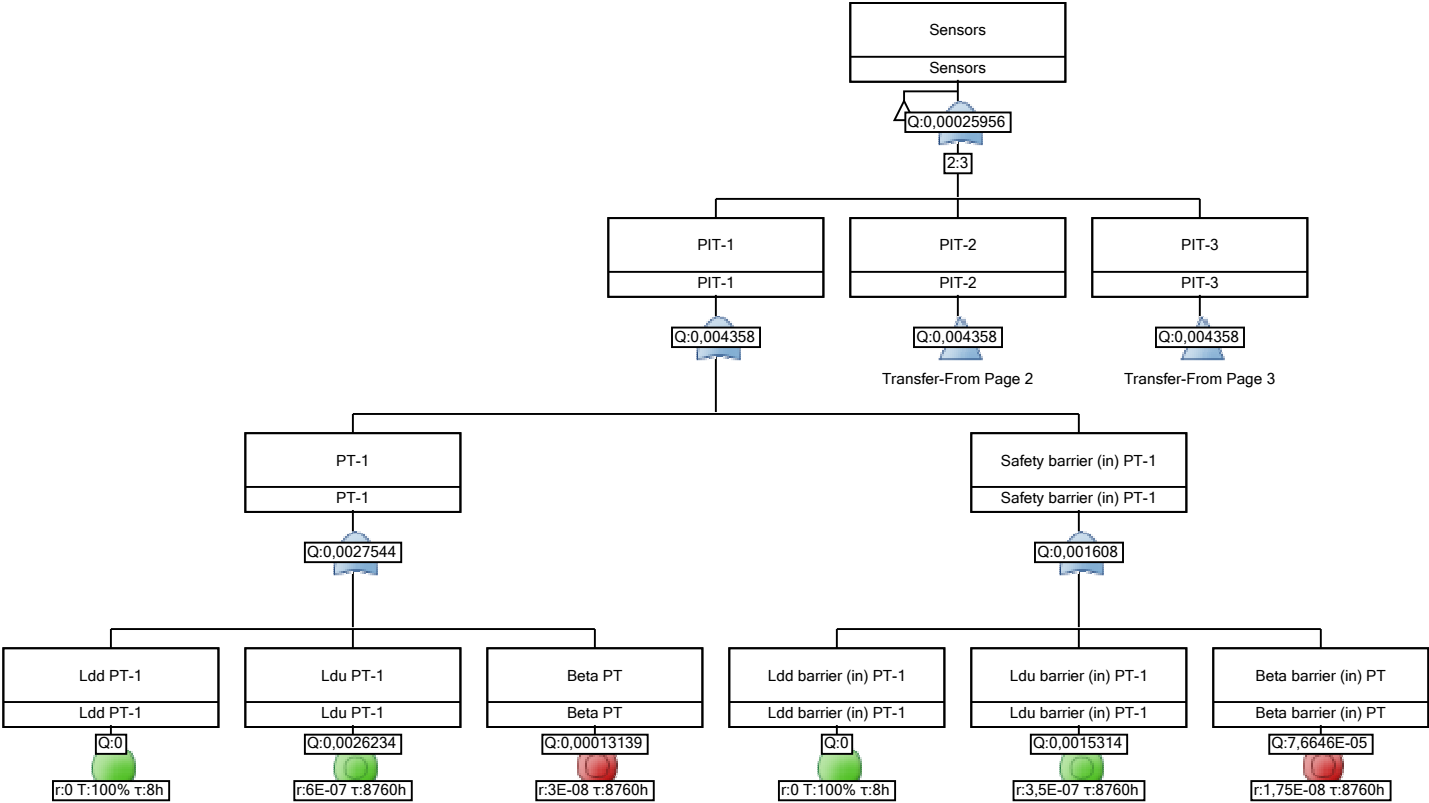












	KPC Western Desert - EGYPT QASR COMPRESSION PROJECT SIL ALLOCATION STUDY	
Project n° 3538-200	DOCUMENT TITLE: SIL VERIFICATION REPORT	Rev. No.: 0
	DOCUMENT NUMBER: 13182I-006	September 2013

ATTACHMENT E – RESULTS SUMMARY

SIF #	INITIATOR	Std. Arch.	PID	FINAL ELEMENT	PID	Required SIL (alloc.)	Required PFD	Calculated PFD	PFD Verified	% PFD Discrepancy	SFF Verified
1	LIT011B HH	1	12311-2	C: ESDV-030A AND ESDV-031A AND ESDV032A AND ESDV033A	12210 /12353	2	4,762E-03	4,791E-02	no	906,152	no (valves body #12)
2	LIT002_032 HH	2	12369	C: ESDV-030A AND ESDV-031A AND ESDV032A AND ESDV033A	12210	2	9,091E-03	4,455E-02	no	390,072	no (valves body #12)
3	LIT037_344 HH	2	12356	C: ESDV-030A AND ESDV-031A AND ESDV032A AND ESDV033A	12210	2	9,091E-03	4,455E-02	no	390,072	no (valves body #12)
4	PIT079A/B/C LL	3	12300-2	C: ESDV-030A AND ESDV-031A AND ESDV032A AND ESDV033A	12210	1	6,667E-02	4,461E-02	yes	N.A.	yes
5	PDIT906 HH	4	12210	I: ESDV-030A	12210	1	2,000E-02	1,548E-02	yes	N.A.	yes
6	PDIT907 HH	4	12210	I: ESDV-031A	12210	1	2,000E-02	1,548E-02	yes	N.A.	yes
7	LIT101 LL	5	12211	C: ESDV103	12211	1	1,000E-01	1,827E-02	yes	N.A.	yes
8	LIT107 HH	6	12211	T: QA-K-8001A AND ESDV101A AND ESDV102A	12212	2	5,000E-03	3,082E-02	no	516,42	no (LT #2, valves body #12)
9	PIT110 LL	7	12212	T: QA-K-8001A AND ESDV101A AND ESDV102A	12212	1	5,000E-02	2,806E-02	yes	N.A.	yes
10	PIT111 HH	7	12212	T: QA-K-8001A AND ESDV101A AND ESDV102A	12212	1	1,538E-02	2,806E-02	no	82,403	yes
11	TIT102 HH	8	12212	T: QA-K-8001A AND ESDV101A AND ESDV102A	12212	1	2,000E-02	2,679E-02	no	33,925	yes
12	VSHH101 HH	9	12212	T: QA-K-8001A AND ESDV101A AND ESDV102A	12212	1	6,667E-02	2,619E-02	yes	N.A.	yes
13	LIT109 LL	5	12212	C: ESDV109	12212	1	1,000E-01	1,827E-02	yes	N.A.	yes

SIF #	INITIATOR	Std. Arch.	PID	FINAL ELEMENT	PID	Required SIL (alloc.)	Required PFD	Calculated PFD	PFD Verified	% PFD Discrepancy	SFF Verified
14	LIT110 HH	6	12212	T: QA-K-8001A AND ESDV101A AND ESDV102A	12212	1	9,524E-02	3,082E-02	yes	N.A.	yes
15	TIT111 HH	8	12212	T: QA-K-8001A AND ESDV101A AND ESDV102A	12212	1	1,000E-01	2,679E-02	yes	N.A.	yes
16	TIT110 HH	8	12212	T: QA-K-8001A AND ESDV101A AND ESDV102A	12212	1	1,000E-01	2,679E-02	yes	N.A.	yes
17	TIT113 LL	10	12213	T: ESD110A (QA-E-8001A cooler motor)	12213	2	3,960E-03	1,549E-02	no	291,0215	yes
18	TIT108A_B_C HH	11	12213	T: QA-K-8001A AND ESDV101A AND ESDV102A	12212	2	9,091E-03	2,417E-02	no	165,903	no (valves body #12)
19	VSHH102A/B/C/D HH	12	12213	T: QA-E-8001A/B/C/D	12212	1	1,000E-01	1,488E-02	yes	N.A.	yes
20	LIT104A LL	-	12214	C: ESDV101 A	12211	NC	1,000E+00	1,159E-02	-	N.A.	-
21	LIT104B HH	6	12214	T: QA-K-8001A AND ESDV101A AND ESDV102A	12212	2	3,333E-03	3,082E-02	no	824,63	no (valves body #12)
22	PDIT908 HH	4	12353	I: ESDV032A	12353	1	2,000E-02	1,548E-02	yes	N.A.	yes
23	PDIT909 HH	4	12353	I: ESDV033A	12353	1	2,000E-02	1,548E-02	yes	N.A.	yes
24	LIT011A LL	13	12311-2	T: P-8006A/B	12311-2	1	1,000E-01	9,821E-03	yes	N.A.	yes
25	PIT066A/B LL	-	12312	T: P-8007A/B	12312	NC	9,091E-01	7,002E-03	-	N.A.	-
26	PIT929A/B HH	-	12312	T: P-8007A/B	12312	NC	1,667E-01	7,002E-03	-	N.A.	-
27	LIT 001 LL	14	12372	T: P-3016	12372	1	2,000E-02	6,852E-03	yes	N.A.	yes
28	LIT 004 LL	14	12373	T: P-4016	12373	1	2,000E-02	7,002E-03	yes	N.A.	yes
29	PDIT910 911 HH	4	12353	I: ESDV034A/35A	12353	1	2,000E-02	1,548E-02	yes	N.A.	yes
30	PDIT912 913 HH	4	12353	I: ESDV036A/37A	12353	1	2,000E-02	1,548E-02	yes	N.A.	yes
31	PIT924 HH	15	12353	C: ESDV-034A AND ESDV 035A	12353	1	1,000E-01	2,660E-02	yes	N.A.	yes
32	PIT076A B C HH	16	12366	C: ESDV-026A AND B	12250/54	2	1,000E-02	2,280E-02	no	127.98	yes
33	LIT002A/3A LL	17	12250-54	C: ESDV001A/B AND T: QA-P-8003A/B/C	12250/54	1	1,000E-01	2,530E-02	yes	N.A.	yes
34	LIT002B/3B HH	5	12250-54	C: ESDV011A/B	12250/54	2	4,545E-03	1,827E-02	no	302,006	no (LT #2, valves body #12)
35	PIT002A/B HH	18	12250-54	C: ESDV011A/B	12250/54	2	1,916E-03	1,548E-02	no	707,9516	no (valves body #12)

SIF #	INITIATOR	Std. Arch.	PID	FINAL ELEMENT	PID	Required SIL (alloc.)	Required PFD	Calculated PFD	PFD Verified	% PFD Discrepancy	SFF Verified
36	LIT021A/B LL	5	12250	C: ESDV026A/B	12250/54	1	1,000E-01	1,827E-02	yes	N.A.	yes
37	VSHH002A/B/C HH	19	12251	T: QA-P-8003A/B/C	12251	1	1,000E-01	5,958E-03	yes	N.A.	yes
38	PIT918A/B/C HH	-	12251	T: QA-P-8003A/B/C	12251	NC	1,000E+00	7,002E-03	-	N.A.	-
39	FIT019A/B/C HH	-	12251	T: QA-P-8003A/B/C	12251	NC	2,500E-01	2,078E-02	-	N.A.	-
40	PIT062 HH	-	12262	C: ESDV-013A OR B	12262	NC	1,000E+00	4,505E-03	-	N.A.	-
41	PIT071A/B LL	-	12261 / 62	T: QA-K-8003A/B AND C: ESDV043 AND ESDV013A OR ESDV013B	12250/61/62	NC	1,000E+00	1,826E-02	-	N.A.	-
42	PIT021A/B HH	20	12261 / 62	T: QA-K-8003A/B AND C: ESDV043 AND ESDV013A OR ESDV013B	12250/61/62	1	1,000E-01	1,826E-02	yes	N.A.	yes
43	TIT004A/B HH	21	12261 / 62	T: QA-K-8003A/B AND C: ESDV043 AND ESDV013A OR ESDV013B	12250/61/62	1	1,000E-01	1,697E-02	yes	N.A.	yes
44	TIT002A/B HH	-	12261 / 62	T: QA-K-8003A/B AND C: ESDV043 AND ESDV013A OR ESDV013B	12250/61/62	not assessed	not assessed	1,697E-02	-	N.A.	-
45	ST001A/B HH	-	12261 / 62	T: QA-K-8003A/B AND C: ESDV043 AND ESDV013A OR ESDV013B	12250/61/62	not assessed	not assessed	1,826E-02	-	N.A.	-
46	PDIT028 HH	4	12302	I: ESDV002A	12302	1	2,000E-02	1,548E-02	yes	N.A.	yes
47	PDIT035 HH	22	12303-1	I: ESDV004A	12303-1	1	2,000E-02	1,203E-02	yes	N.A.	yes
48	PDIT099 HH	4	12354	I: ESDV010A	12354	1	2,000E-02	1,548E-02	yes	N.A.	yes
49	PDIT925 HH	4	12368	I: ESDV028A	12368	1	2,000E-02	1,548E-02	yes	N.A.	yes
50	TIT007 HH	23	12302	T: QA-E-8002	12302	1	9,950E-02	5,610E-03	yes	N.A.	yes
51	TIT005 HH	23	12302	T: QA-E-8002	12302	1	1,000E-01	5,610E-03	yes	N.A.	yes
52	FIT026 B LL	24	12302	T: QA-E-8002	12302	1	1,000E-01	1,984E-02	yes	N.A.	yes
53	TIT011A/B HH	23	12303-01/02	T: QA-E-8003A/B	12303-01/02	1	9,950E-02	5,610E-03	yes	N.A.	yes
54	TIT009A/B HH	23	12303-01/02	T: QA-E-8003A/B	12303-01/02	2	9,950E-03	5,610E-03	yes	N.A.	yes
55	FIT027 LL	24	12303-01/02	T: QA-E-8003A/B	12303-01/02	1	1,000E-01	1,984E-02	yes	N.A.	yes

SIF #	INITIATOR	Std. Arch.	PID	FINAL ELEMENT	PID	Required SIL (alloc.)	Required PFD	Calculated PFD	PFD Verified	% PFD Discrepancy	SFF Verified
56	LIT005 B LL	5	12305	C: ESDV 005	12305	1	1,000E-01	1,827E-02	yes	N.A.	yes
57	LIT005 A HH	25	12305	C: ESDV003 AND ESDV004		2	5,000E-03	2,255E-02	no	350,94	no (LT #2, valves body #13)
58	FIT004 LL	26	12305	T: QA-E-8005A AND B	12307-1	1	9,091E-02	2,241E-02	yes		yes
59	PIT044A HH	27	12305	ESDV003 AND 004A/B	12302/ 120303-1	2	5,000E-03	1,976E-02	no	295,28	no (valves body #13)
60	PIT044B LL	27	12305	ESDV003 AND 004A/B	12302/ 120303-1	2	5,000E-03	1,976E-02	no	295,28	no (valves body #13)
61	PITXX1 HH [1]	18	12307	ESDVXX1		2	1,000E-02	1,548E-02	no	54,78	yes
62	TIT022A/B HH	23	12307-1	T: QA-E-8005A/B	12307-1	1	9,950E-02	5,610E-03	yes	N.A.	yes
63	TIT019A/B HH	23	12307-1	T: QA-E-8005A/B	12307-1	2	9,950E-03	5,610E-03	yes	N.A.	yes
64	TDIT034 LL	28	12307-1	T: QA-K-8001A AND ESDV101A AND ESDV102A AND T: QA-K-8001B AND ESDV201A AND ESDV202A AND T: QA-K-8001C AND ESDV301A AND ESDV302A AND T: QA-K-8001D AND ESDV401A AND ESDV402A	12213,12223, 12233, 12243	2	1,000E-02	9,717E-02	no	871,68	yes
65	LIT008A LL	5	12308-2	C: ESDV 008	12308-2	1	1,000E-01	1,827E-02	yes	N.A.	yes
66	PIT053B LL	29	12308-2	O: ESDV025 AND ESDV048	12354/ 12368	3	1,000E-03	1,805E-02	no	1704,6	yes
67	PIT053B HH	30	12308-2	C: ESDV025 AND ESDV048 AND ESDV007	12308-1/ 12354/ 12368	2	5,000E-03	3,415E-02	no	583,04	no (valves body #13)
68	TIT036 HH	23	12308-1	T: QA-E-8006	12308-1	1	9,950E-02	5,610E-03	yes	N.A.	yes

SIF #	INITIATOR	Std. Arch.	PID	FINAL ELEMENT	PID	Required SIL (alloc.)	Required PFD	Calculated PFD	PFD Verified	% PFD Discrepancy	SFF Verified
69	TIT037 HH	23	12308-1	T: QA-E-8006	12308-1	2	9,950E-03	5,610E-03	yes	N.A.	yes
70	FIT028 B LL	24	12308-1	T: OA-E-8006	12308-1	1	1,000E-01	1,984E-02	yes	N.A.	yes
71	PIT075A LL	18	12300-1	C: ESDV038	12300-1	1	5,000E-02	1,548E-02	yes	N.A.	yes
72	PIT075B LL	27	12300-1	C: ESDV015	12300-1	1	5,000E-02	1,976E-02	yes	N.A.	yes
73	PIT075C LL	27	12300-1	C: ESDV016	12300-1	1	5,000E-02	1,976E-02	yes	N.A.	yes
74	PIT085A/B/C LL	31	12301-2	C: ESDV024	12301-2	1	9,091E-02	8,166E-03	yes	N.A.	yes
75	TIT014 HH	23	12301-2	T: QA-E-8007	12301-2	1	9,950E-02	5,610E-03	yes	N.A.	yes
76	TIT006 HH	23	12301-2	T: QA-E-8007	12301-2	2	9,901E-03	5,610E-03	yes	N.A.	yes
77	PITXX2 HH [2]	18	12301-2	ESDVXX2		1	1,000E-01	1,548E-02	yes	N.A.	yes

[1]: The SIF shall be analysed with flash gas compressor vendor

[2]: A technical recommendation has been raised by the team in order to reduce the risk level and the correspondent risk value